THE No 1 UK MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

EPE EVERYDAY PRACTICAL ELECTRONICS

www.epemag.com

HIGH PERFORMANCE MOTOR SPEED CONTROLLER

- Silky smooth control from near zero to full speed
- Works on any appliance with universal (brush-type) motors
- Rated up to 2300W

PRECISION 10V DC REFERENCE FOR CHECKING DMMs

A DC voltage source that provides 10.000V DC

MUSICOLOUR IrDA ACCESSORY

Add a wireless infrared port – works with virtually any microcontroller project

PLUS

TEACH-IN 2011 – PART 8

A must-read introduction to all aspects of filters

$8.99US £4.25UK
JUNE 2011 PRINTED IN THE UK
06
0 74470 07806 7

Low-Power Microcontrollers for Battery-Friendly Design

Microchip Offers Lowest Currents for Active and Sleep Modes

Extend the battery life in your application using PIC® microcontrollers with nanoWatt XLP Technology and get the industry's lowest currents for Active and Sleep modes.

Microchip's new peripheral-rich PIC12F182X, PIC16F182X and PIC16F19XX families offer active currents of less than 50 µA and sleep currents down to 20 nA. These products enable you to create battery-friendly designs that also incorporate capacitive touch sensing, LCD, communications and other functions which help differentiate your products in the marketplace.

Microchip's Enhanced Mid-range 8-bit architecture provides up to 50% increased performance and 14 new instructions that result in up to 40% better code execution over previous-generation 8-bit PIC16 MCUs.

PIC12F182X and PIC16F182X families include:

- Packages ranging from 8 to 64 pins
- mTouch™ capacitive touch-sensing
- Multiple communications peripherals
- Dual I²C™/SPI interfaces
- PWM outputs with independent time bases
- Data signal modulator

PIC16F19XX family includes:

- mTouch capacitive touch-sensing
- LCD drive
- Multiple communications peripherals
- More PWM channels, with independent timers
- Up to 28 KB of Flash program memory
- Enhanced data EEPROM
- 32-level bandgap reference
- Three rail-to-rail input comparators

GET STARTED IN 3 EASY STEPS

1. View the Low Power Comparison videos
2. Download the Low Power Tips 'n Tricks
3. Order samples and development tools
   www.microchip.com/XLP

PIC16F193X 'F1' Evaluation Platform - DM164130-1

Intelligent Electronics start with Microchip

microchip DIRECT www.microchipdirect.com

www.microchip.com/xlp

MICROCHIP

ISSN 0262 3617

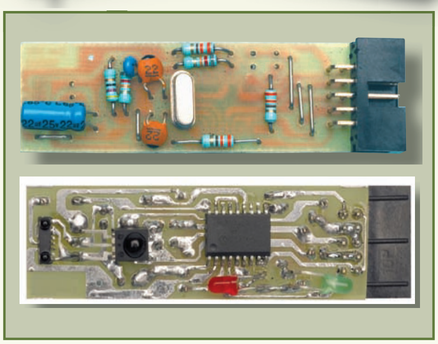
• PROJECTS • THEORY •
• NEWS • COMMENT •
• POPULAR FEATURES •

VOL. 40. No 6 June 2011

EPE EVERYDAY PRACTICAL ELECTRONICS

INCORPORATING ELECTRONICS TODAY INTERNATIONAL

www.epemag.com



Projects and Circuits

Series and Features

Regulars and Services

Our July 2011 issue will be published on Thursday 9 June 2011, see page 80 for details.

Quasar Electronics Limited
PO Box 6935, Bishops Stortford
CM23 4WP, United Kingdom
Tel: 01279 467799
Fax: 01279 267799
E-mail: sales@quasarelectronics.com
Web: www.quasarelectronics.com

QUASAR electronics
The Electronic Kit Specialists Since 1993

All prices INCLUDE 20.0% VAT.
Postage & Packing Options (Up to 0.5Kg gross weight): **UK Standard 3-7 Day Delivery** - £4.95; **UK Mainland Next Day Delivery** - £11.95; **Europe (EU)** - £12.95; **Rest of World** - £14.95 (up to 0.5Kg).
!Order online for reduced price Postage (from just £1)
Payment: **We accept all major credit/debit cards. Make PO's payable to Quasar Electronics.**
Please visit our online shop now for full details of over 500 electronic kits, projects, modules and publications. Discounts for bulk quantities.

01279 Credit Card Sales 467799

PIC & ATMEL Programmers

We have a wide range of low cost PIC and ATMEL Programmers. Complete range and documentation available from our web site.

Programmer Accessories:
40-pin Wide ZIF socket (ZIF40W) £14.95
18Vdc Power supply (PSU121) £24.95
Leads: Parallel (LDC136) £3.95 / Serial (LDC441) £3.95 / USB (LDC644) £2.95

USB & Serial Port PIC Programmer

USB/Serial connection. Header cable for ICSP. Free Windows XP software. See website for PICs supported. ZIF Socket and USB lead extra. 18Vdc.
Kit Order Code: 3149EKT - **£49.95**
Assembled Order Code: AS3149E - **£59.95**
Assembled with ZIF socket Order Code: AS3149EZIF - **£74.95**

USB Flash/OTP PIC Programmer

USB PIC programmer for a wide range of Flash & OTP devices—see website for details. Free Windows Software. ZIF Socket and USB lead not included. Supply: 16-18Vdc.
Assembled Order Code: AS3150 - **£49.95**
Assembled with ZIF socket Order Code: AS3150ZIF - **£64.95**

ATMEL 89xxxx Programmer

Uses serial port and any standard terminal comms program. 4 LED's display the status. ZIF sockets not included. Supply: 16Vdc.
Kit Order Code: 3123KT - **£28.95**
Assembled Order Code: AS3123 - **£39.95**

Introduction to PIC Programming

Go from complete beginner to burning a PIC and writing code in no time! Includes 49 page step-by-step PDF Tutorial Manual, Programming Hardware (with LED test section), Win 3.11—XP Programming Software (Program, Read, Verify & Erase), and 1rewritable PIC16F84A that you can use with different code (4 detailed examples provided for you to learn from). PC parallel port.
Kit Order Code: 3081KT - **£16.95**
Assembled Order Code: AS3081 - **£24.95**

PIC Programmer Board

Low cost PIC programmer board supporting a wide range of Microchip® PIC™ microcontrollers. Requires PC serial port. Windows interface supplied.
Kit Order Code: K8076KT - **£39.95**

PIC Programmer & Experimenter Board

The PIC Programmer & Experimenter Board with test buttons and LED indicators to carry out educational experiments, such as the supplied programming examples. Includes a 16F627 Flash Microcontroller that can be reprogrammed up to 1000 times for experimenting at will. Software to compile and program your source code is included.
Kit Order Code: K8048KT - **£39.95**
Assembled Order Code: VM111 - **£59.95**

Controllers & Loggers

Here are just a few of the controller and data acquisition and control units we have. See website for full details. 12Vdc PSU for all units: Order Code PSU303 £9.95

USB Experiment Interface Board

5 digital input channels and 8 digital output channels plus two analogue inputs and two analogue outputs with 8 bit resolution.
Kit Order Code: K8055KT - **£39.95**
Assembled Order Code: VM110 - **£64.95**

Rolling Code 4-Channel UHF Remote

State-of-the-Art. High security. 4 channels. Momentary or latching relay output. Range up to 40m. Up to 15 Tx's can be learnt by one Rx (kit includes one Tx but more available separately). 4 indicator LED 's. Rx: PCB 77x85mm, 12Vdc/6mA (standby). Two *& Ten Channel versions also available.*
Kit Order Code: 3180KT - **£54.95**
Assembled Order Code: AS3180 - **£64.95**

Computer Temperature Data Logger

Serial port 4-channel temperature logger. °C or °F. Continuously logs up to 4 separate sensors located 200m+ from board. Wide range of free software applications for storing/using data. PCB just 45x45mm. Powered by PC. Includes one DS1820 sensor.
Kit Order Code: 3145KT - **£24.95**
Assembled Order Code: AS3145 - **£31.95**
Additional DS1820 Sensors - **£4.95 each**

Remote Control Via GSM Mobile Phone

Place next to a mobile phone (not included). Allows toggle or auto-timer control of 3A mains rated output relay from any location with GSM coverage.
Kit Order Code: MK160KT - **£14.95**

Most items are available in kit form (KT suffix) or pre-assembled and ready for use (AS prefix).

4-Ch DTMF Telephone Relay Switcher

Call your phone number using a DTMF phone from anywhere in the world and remotely turn on/off any of the 4 relays as desired. User settable Security Password, Anti-Tamper, Rings to Answer, Auto Hang-up and Lockout. Includes plastic case. 130 x 110 x 30mm. Power: 12Vdc.
Kit Order Code: 3140KT - **£79.95**
Assembled Order Code: AS3140 - **£94.95**

8-Ch Serial Port Isolated I/O Relay Module

Computer controlled 8 channel relay board. 5A mains rated relay outputs and 4 opto-isolated digital inputs (for monitoring switch states, etc). Useful in a variety of control and sensing applications. Programmed via serial port (use our new Windows interface, terminal emulator or batch files). Serial cable can be up to 35m long. Includes plastic case 130x100x30mm. Power: 12Vdc/500mA.
Kit Order Code: 3108KT - **£74.95**
Assembled Order Code: AS3108 - **£89.95**

Infrared RC 12–Channel Relay Board

Control 12 onboard relays with included infrared remote control unit. Toggle or momentary. 15m+ range. 112 x 122mm. Supply: 12Vdc/0.5A
Kit Order Code: 3142KT - **£64.95**
Assembled Order Code: AS3142 - **£74.95**

Audio DTMF Decoder and Display

Detect DTMF tones from tape recorders, receivers, two-way radios, etc using the built-in mic *or* direct from the phone line. Characters are displayed on a 16 character display as they are received and up to 32 numbers can be displayed by scrolling the display. All data written to the LCD is also sent to a serial output for connection to a computer. Supply: 9-12V DC (Order Code PSU303). Main PCB: 55x95mm.
Kit Order Code: 3153KT - **£37.95**
Assembled Order Code: AS3153 - **£49.95**

3x5Amp RGB LED Controller with RS232

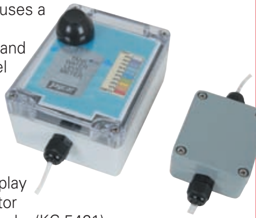
3 independent high power channels. Preprogrammed or user-editable light sequences. Standalone option and 2-wire serial interface for microcontroller or PC communication with simple command set. Suitable for common anode RGB LED strips, LEDs and incandescent bulbs. 56 x 39 x 20mm. 12A total max. Supply: 12Vdc.
Kit Order Code: 3191KT - **£27.95**
Assembled Order Code: AS3191 - **£37.95**

Test & Lighting Kits for Electronic Enthusiasts

KIT OF THE MONTH

PIC Based Water Tank Level Meter Kit

KC-5460 £39.50 plus postage & packing



This PIC-based unit uses a pressure sensor to monitor water level and will display tank level via an RGB LED at the press of a button. The kit can be expanded to include an optional wireless remote display panel that can monitor up to ten separate tanks (KC-5461), or you can add a wireless remote controlled mains power switch (KC-5462) to control remote water pumps. Kit includes electronic components, case, screen printed PCB and pressure sensor.

Telemetry Base Station for Water Tank Level Meter

KC-5461 £31.00 plus postage & packing

This Base Station is intended for use with the telemetry version of the KC-5460 water tank level meter and can handle data transmissions from up to 10 level meters and display the results on a 2-line 32-character LCD module. In bargraph mode, it can show up to 10 tank levels simultaneously, while the digital readout mode shows individual tank levels to 1%. Includes silk screened PCB, case, electronic components, receiver module and the RF transmitter upgrade for one tank level meter. Requires transmitter module to control KC-5462 remote switch. 9-12VDC, 100mA required.

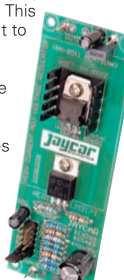
UHF Remote Controlled Mains Switch

KC-5462 £36.25 plus postage & packing

This UHF system will operate up to 200m and is perfect for remote power control systems etc. The switch can be activated using the included hand held controller or our KC-5461 water tank level sensor base station. Kit includes case, PCB with overlay, RF modules and all electronic components.

Improved Low Voltage Adaptor

KC-5463 £6.75 plus postage & packing



Need to operate a CD, DVD or MP3 player from the cigarette lighter socket in your car? This adaptor has a push-on jumper shunt to select one of six common output voltages 3V, 5V, 6V, 9V, 12V or 15V and, when used with an appropriate input voltage and heat sink, can deliver up to four amps at the selected output voltage. Kit includes PCB and all specified components.

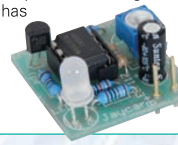
- PCB: 108 x 37mm

Please note that to ensure trouble free 4 amp output, a heatsink with a thermal resistance of 1.4°C per watt, and an input voltage 3VDC above the output voltage is required.

LED Battery Voltage Indicator

KA-1778 £3.75 plus postage & packing

This tiny circuit measures just 25mm x 25mm and will provide power indication and low voltage indication using a bi-colour LED, and can be used in just about any piece of battery operated equipment. Current consumption is only 3mA at 6V and 8mA at 10V and the circuit is suitable for equipment powered from about 6-30VDC. With a simple circuit change, the bi-colour LED will produce a red glow to indicate that the voltage has exceeded a preset value.



- PCB, bi-colour LED and all specified electronic components supplied

Universal +/-15V Power Supply

KC-5038 £5.50 plus postage & packing

This small kit enables you to obtain +15V, -15V or ±15V DC from a number of different transformer and rectifier combinations.

- ±15V rails from 30V AC centre tapped (MM-2007) transformer
- Kit includes PCB and all components for all options listed above
- Transformer not included
- PCB: 64 x 41mm

Don't just sit there BUILD SOMETHING!

Versatile Regulated Voltage Adaptor

KA-1797 £3.00 plus postage & packing

A low-powered DC converter for many car applications, for example, where you need a reliable voltage source for a portable CD player or similar battery-powered device. Alternatively use as a peripheral computer power supply to power external Zip drives, powered speakers, modems, music/MIDI keyboards, etc. Just plug its input into your PC's internal power supply cable and get selectable regulated voltage out from 3 to 15VDC (Input voltage MUST be larger than the required output voltage)

- Output current capable up to 1.5amps (heatsink required)
- PCB plus electronic components included
- PCB: 52 x 19mm

3V to 9V DC to DC Converter Kit

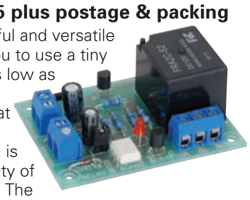
KC-5391 £6.00 plus postage & packing

This great little converter allows you to use regular Ni-Cd or Ni-MH 1.2V cells, or alkaline 1.5V cells for 9V applications. Using low cost, high capacity rechargeable cells, the kit will pay for itself in no-time! You can use any 1.2-1.5V cells you desire. Imagine the extra capacity you would have using two 9000mAh D cells in replacement of a low capacity 9V cell. Kit supplied with PCB, & all electronic components.

- PCB: 59 x 29mm

DC Relay Switch Kit

KC-5434 £6.25 plus postage & packing



An extremely useful and versatile kit that enables you to use a tiny trigger current - as low as 400µA at 12V to switch up to 30A at 50VDC. It has an isolated input, and is suitable for a variety of triggering options. The kit includes PCB with overlay and all electronic components with clear instructions.

Battery Kits

SLA Battery Health Checker Kit

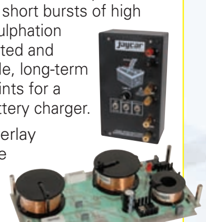
KC-5482 £29.00 plus postage & packing

Check the health of SLA batteries prior to charging or zapping with a simple LED condition indication of fail, poor, fair, ok, and good. It provides stable readings for 6V, 12V and 24V, and gives a choice of test current pulse levels to suit batteries of different capacities. Kit includes PCB with overlay, electronic components and case with machined and silk-screened front panel.

- PCB: 185 x 101mm

Battery Zapper Mk III

KC-5479 £29.00 plus postage & packing



It attacks a common cause of failure in lead acid batteries: sulphation, which can send a battery to an early grave. The circuit produces short bursts of high levels of energy to reverse the sulphation effect. The circuit has been updated and revamped to provide more reliable, long-term operation. It still includes test points for a DMM and binding posts for a battery charger.

- PCB with solder mask and overlay
- Screen printed machined case
- 6, 12 & 24VDC

Note: Not recommended for use with gel batteries

3-Step MPPT Solar Charge Controller

KC-5500 £47.00 plus postage & packing

Charge controllers are essential for solar setups, although commercial units can run into several hundred dollars. Designed for use with 40W to 120W 12V solar panels and lead acid batteries, this solar charger provides 3-stage charging with the option of equalisation and with MPPT (Maximum Power Point Tracking). Operation is for 12V and the kit configured for this voltage, a 24V upgrade will be available in future. Kit includes PCB, all components and case.

- MPPT (maximum power point tracking) charging
- Charge indicator LEDs
- Temperature compensation for charge voltage
- Optional 24V 80W to 240W operation upgrade

Post & Packing Charges

Order Value	Cost
£10 - £49.99	£5
£50 - £99.99	£10
£100 - £199.99	£20
£200 - £499.99	£30
£500+	£40
Max weight 12lb (5kg)	
Heavier parcels POA	
Minimum order £10	

Note: Products are despatched from Australia, so local customs duty & taxes may apply.

- **All pricing in Pounds Sterling**
- **Minimum order £10**

Prices valid until 30/6/2011

HOW TO ORDER

WEB:	www.jaycarelectronics.co.uk
PHONE:	0800 032 7241*
FAX:	+61 2 8832 3118*
EMAIL:	techstore@jaycarelectronics.co.uk
POST:	P.O. Box 107, Rydalmere NSW 2116 Australia

*Australian Eastern Standard Time
(Monday - Friday 09.00 to 17.30 GMT + 10 hours)
Expect 10-14 days for air parcel delivery

Order online: www.jaycarelectronics.co.uk

Jaycar Electronics

0845 251 4363

Catalogues Available

velleman projects

UK's No 1 source for VELLEMAN® Kits

Velleman Kits

K1803	Universal Mono Pre-Amplifier Kit	4.34
K1823	1A Power Supply Kit	6.95
K2543	Electronic Transistor Ignition Kit	11.30
K2570	Universal 5 - 14VDC Power Supply Kit	9.42
K2572	Universal Stereo Pre-Amplifier Kit	7.95
K2573	Stereo Pre-Amplifier for MD Pick-Ups Kit	8.00
K2579	Universal Stop/Start Timer Kit	6.76
K2599	Windshield Wiper or Interval Timer Kit	10.90
K2601	Stroboscope Kit	13.14
K2604	Police Siren Kit	8.12
K2622	AM/FM Antenna Amplifier Kit	9.32
K2625	Digital Tachometer Kit	23.64
K2633	Relay Card Kit	14.28
K2634	Quad Triac Switch Card Kit	13.36
K2636	Speed Controller Kit	16.23
K2639	Liquid level Controller Kit	12.69
K2644	Frost Indicator Kit	8.31
K2649	Thermostat with LCD Kit	32.73
K2651	LCD Panel Meter Kit	19.31
K2655	Electronic Watchdog Kit	22.13
K2661	Dual Input Amplifier Module Kit	16.55
K3400	Dual Electronic Dice Kit	10.91
K3500	Multifunction car Courtesy Light Kit	10.01
K3502	Parking Radar Kit	27.35
K3504	Car Alarm Kit	13.41
K3505	Car Light Warning Alarm Kit	9.18
K4001	7W Mono Amplifier Kit	6.90
K4003	2 x 30W Audio Power Amplifier Kit	16.96
K4004B	200W Mono/Stereo Amplifier Kit	45.71
K4005B	400W Mono/Stereo Amplifier Kit	62.85
K4006	Power Supply for K4004B and K4005B Kit	10.45
K4010	300W Mono Mosfet Amplifier Kit	138.19
K4040	Stereo Valve Amplifier/Chrome Kit	765.92
K4040B	Stereo Valve Amplifier/Black Kit	809.94
K4102	Guitar Preamp with Headphone Output	19.85
K4301	Pink Noise Generator Kit	8.31
K4304	Mono VU Meter 10 LEDs Kit	9.95
K4305	Stereo VU Meter 2 x 10 LEDs Kit	15.95
K4306	Precision Stereo VU Meter 2 x 15 LEDs Kit	24.95
K4307	Audio Power Meter Kit	15.35
K4401	Sound Generator Kit	15.95
K4600	Video and RGB Converter/Processor Kit	95.61
K4601	Audio/Video TV Modulator Kit	25.89
K4700	2-Channel Loudspeaker Protection Kit	13.70
K4701	Loudspeaker DC-Protection Kit	10.00
K4900	Telephone Amplifier Kit	8.50
K5200	4-Channel Multi-Function Running Light Kit	18.08
K5201	Light Computer Ki	
K5203	Dual Function St	
K5600R	Advertisement Li	
K6001	Temperature Se	
K6002	Temperature Co	
K6003	Temperature Se	
K6200	0 to 60 Hours St	
K6400	Code Lock Kit	
K6501	Remote Control	
K6600	Multitone Chime	
K6712	IR Remote Contr	
K6714	Universal Relay	
K6714-16	Universal Relay	
K7000	Signal Tracer/Inj	
K7101	Mains Voltage Det	
K7102	Metal Detector Kit	7.62
K7105	Handheld LCD Osciloscope Kit	135.28
K7203	3-30V 3A Power Supply Kit	25.10
K7300	Universal Battery Charger/Discharger Kit	13.84
K7302	Low Cost Universal Battery Charger Kit	6.35
K8000	PC Interface Board Kit	74.95
K8004	DC to Pulse Width Modulator Kit	9.95
K8005	Stepper Motor Card Kit	25.90
K8006	Domotica Light System - Busprint Kit	25.52
K8008	Multifunction Relay Module Kit	12.90
K8009	Multifunctional Clock Kit	53.10
K8012	Lead Acid Battery Charger/Conditioner	27.98
K8015	Multifunction Relay Switch Kit	14.94
K8016	PC Function Generator 0 - 1MHz Kit	99.98
K8017	3-Channel Sound Light with Microphone	33.80
K8020	Valve Control Amplifier Kit	207.93
K8021	High-End Control Amplifier Kit	155.37
K8023	10-Channel, 2-Wire Remote Control Kit	24.41
K8026	Suppressed 3.5A Dimmer Kit	9.94
K8027	Relay Output Module (for K8006) Kit	9.95
K8028	Multifunction Dimmer Kit	22.20
K8029	Slow On-Off Dimmer Kit	13.60
K8031	One Channel Digital PC Scope Kit	100.99
K8032	4 channel Running Light Kit	20.58
K8033	Power Blinker Kit	13.04
K8035	Multifunctional Up/Down Counter Kit	17.85
K8036	Video Signal Cleaner Kit	20.58
K8037	Bus Dimmer for Home Light System Kit	12.70
K8038	Power Dimmer, Push-Button Controlled Kit	14.80
K8039	1 Channel DMX Controlled Power Dimmer	29.95
K8040	High-End MOSFET Power Amplifier Kit	181.45
K8041	Fan Timer Kit	10.57

K8042	Symmetric 1A Power Supply Kit	7.78
K8044	12V 10-Channel Light Effect Generator Kit	21.44
K8045	Programmable Message Board with LCD	32.92
K8046	User-Definable 8-Channel Touch Panel Kit	40.63
K8047	4-Channel Recorder/Logger Kit	29.01
K8048	PIC Programmer and Experiment Board	24.65
K8049	15-Channel IR Transmitter Kit	25.73
K8050	15-Channel IR Receiver Kit	18.38
K8051	15-Channel IR Remote Stick Kit	14.35
K8055	USB Experiment Interface Board Kit	24.80
K8056	8-Channel Relay Card Kit	30.45
K8057	2-Channel RF Remote Receiver	17.19
K8058	8-Channel RF Remote Control Kit	25.73
K8059	2-Channel RF Code-Lock Transmitter Kit	11.52
K8060	Discrete Power Amplifier 200W Kit	12.85
K8061	Extended USB Interface Board Kit	
K8062	USB Controlled DMX Interface Ki	
K8063	2 Modular Lights with Serial Inte	
K8064	DC Controlled Dimmer Kit	
K8065	Pocket Audio Generator Kit	
K8066	3W Mono Amplifier Kit	
K8067	Universal Temperature Sensor K	
K8068	Dimmer for Electronic Transform	
K8070	1-Channel RF Receiver (for K805	
K8071	1W/3W High Power LED Driver	
K8072	DMX Controlled Relay Kit	
K8074	USB to Remote control Transmitt	
K8075	Power Saver/Timer Kit	
K8076	PIC Programmer Board Kit	
K8077	Subwoofer Kit	
K8081	Powerblock Kit	
K8082	Safe Style Codelock Kit	16.56
K8084	Volume & Tone Control Pre-Amplifier Kit	13.60
K8086	Telephone Ring Detector & Relay Output	11.08
K8087	Telephone Ring with Buzzer and LED Kit	10.83
K8088	RGB Controller Kit	15.15
K8089	Big Digital Clock, Temp Display Kit	40.75
K8090	8 Channel USB Relay Card Kit	39.95
K8091	LED Clock with Light Dimmer Function Kit	22.49
K8092	Optical proximity switch Kit	17.45
K8095	SD/HCSD MP3 Player Kit	39.99
K8098	Audio Analyser Kit	31.65
K8099	Nixie Clock Kit	64.96
K8100	Video Digitiser Card for PC Kit	113.69

Velleman Mini Kits

MK100	Electronic Christmas Tree Minikit	5.63
MK101	Flashing LED Sweetheart Minikit	6.25
	Flashing LED's Minikit	2.99
	Sound to Light Minikit	4.21
	Electronic Cricket Minikit	6.73
	Signal Generator Minikit	4.21
	Metronome Minikit	6.90
	LED Running Light Minikit	6.15
	Water Alarm Minikit	3.74
	Electronic Dice Minikit	4.45
	Simple One Channel Light Organ Minikit	5.84
	Interval Timer Minikit	4.60
	Brain Game Minikit	5.95
	Siren Sound Generator Minikit	5.40
	Low Voltage Light Organ Minikit	7.53
	Pocket VU Meter Minikit	4.25
	Riding Santa Minikit	12.45
MK117	Delux Xmas Tree Minikit	12.68
MK118	FM Radio Minikit	14.73
MK119	Roulette Minikit	11.82
MK120	Light Barrier Minikit	6.90
MK121PAL	Classic TV Game Minikit	10.70
MK122	Animated Bell with 83 LED's Minikit	8.25
MK123	Rolling Clock Minikit	14.79
MK124	Rolling Message Minikit	11.91
MK125	Light Sensitive Switch Minikit	3.95
MK126	Car Alarm Simulator Minikit	4.22
MK127	Running Microbug Minikit	9.02
MK128	Kitchen Timer Minikit	11.55
MK129	Crawling Microbug Minikit	11.48
MK130	3D Xmas Tree Minikit	7.69
MK131	Traffic Light Minikit	6.85
MK132	Cable Polarity Checker Minikit	5.05
MK133	Quiz Table Minikit	6.85
MK134	Steam Engine Sound Generator Minikit	7.47
MK135	Electronic Decision Maker Minikit	3.38
MK136	Super Stereo Ear Minikit	7.44
MK137	IR Remote Checker Minikit	4.43
MK138	Thermostat Minikit	4.55
MK139	Clap On/Off Switch Minikit	10.80
MK140	Karaoke Minikit	8.67
MK141	SMD Happy Face Minikit	4.17
MK142	SMD Xmas Tree Minikit	5.29
MK143	White LED Flashlight Minikit	7.07
MK144	Flashing Heart Minikit	5.29
MK145	Halloween Pumpkin Minikit	7.63
MK146	Pocket VU Meter Minikit (with Enclosure)	7.44
MK147	Dual White LED Stroboscope Minikit	5.20
MK148	Dual Super Bright Flashing Red Lights	4.43
MK149	Love Tester Minikit	11.15
MK150	Shaking Dice Minikit	8.49
MK151	Digital LED Clock Minikit	15.09
MK152	Wheel of Fortune Minikit	3.95
MK153	Jumbo Single Digit Clock Minikit	12.53
MK154	5 in 1 Emergency Tool Minikit	11.84
MK155	Magic Message Minikit	11.84
MK157	LCD Mini Message Board Minikit	15.96
MK158	LCD Mini Message Board with Backlight	21.14
MK159	Brain Game Minikit	10.47
MK160	Remote Control via GSM Mobile Phone	8.93
MK161	2-Channel IR Remote Receiver Minikit	9.95
MK162	2-Channel IR Remote Transmitter Minikit	8.49
MK163	Electronic Stereo Volume Control Minikit	10.90
MK164	IR Electronic Volume Control Minikit	14.79
MK165	Crawling Bug Minikit	13.89
MK166	Animated Ghost Minikit	9.09
MK167	Electronic Candle Minikit	3.81
MK168	Alarm Sensor Simulator Minikit	5.95
	tar (Red) Minikit	6.20
	(Yellow) Minikit	6.20
	ct Star Minikit	10.98
	inikit	6.71
	inikit	7.83
	er Minikit	8.50
	Record/Playback Minikit	11.87
	iley Minikit	7.45
	ow Minikit	8.49
	it	4.90
	lasher Minikit	6.30
	ader Minikit	14.25
	ver LED Flasher Minikit	10.50
	ge indicator LED Minikit	2.43
	hamber Minikit	11.43
MK184	Electronic RGB Candle	5.52
MK185	Solar Bug Minikit	7.89

Velleman Modules - Assembled

VM100	200W Power Amplifier Module	38.54
VM101	Multifunctional Dimmer Module	34.90
VM103	Blinking Module	34.43
VM105	AC Power Slave Module	34.43
VM106	Video Signal Cleaner Module	30.44
VM107	Multifunctional Counter Module	38.91
VM110	USB Interface Card Module	34.90
VM111	PIC Programmer and Experiment Module	32.60
VM112	Personal Animated Badge Module	19.95
VM113	Stereo Amplifier Module 2 x 30W	19.25
VM114	7W Mono Audio Amplifier Module	7.95
VM116	USB Controlled DMX Interface Module	67.15
VM118	8-Channel RF Remote Control Set Module	68.77
VM118R	8-Channel RF Remote Transmitter Module	36.02
VM119	One Channel Dual Output Receiver	19.40
VM120	10-Channel Light Effect Generator	32.02
VM121	15-Channel Infrared Transmitter Module	36.02
VM122	15-Channel Infrared Receiver Module	29.62
VM124	1A Power Supply Module	7.39
VM125	Ultrasonic Radar Module	26.54
VM129	8-Channel Relay Card Module	33.29
VM130	2-Channel RF Remote Control Set Module	35.45
VM130T	2-Channel RF Remote Control Transmitter	12.90
VM131	Dimmer for Electronic Transformers	24.04
VM132	Universal Temperature Sensor Module	13.04
VM133	Energy Saver Module	18.15
VM134	PIC Programmer Board Module	36.90
VM135	Magical Dimmer Module	13.58
VM136	Interval Timer Module	6.30
VM137	Thermostat Module 5° - 30°C Module	7.95
VM138	DMX Controlled Relay Module	21.74
VM139	IR Remote Checker Module	7.64
VM140	Extender USB Interface Board Module	79.95
VM141	Start/Stop Timer Module	12.95
VM142	Mini-Pic Application Module	26.00
VM143/1W	1W High Power LED Driver Module	9.85
VM143/3W	3W High Power LED Driver Module	9.95
VM144	Telephone Ring Detector & Relay output	14.65
VM145	Digital Panel Thermometer Min/Max	23.35
VM146	RGB Controller Module	22.52
VM147	Panel Counter Module	23.35
VM148	Panel Thermostat Module	26.80
VM150	RGB LED Dimmer for DIN rail	31.00
VM151	RGB Controller Module & remote control	26.35
VM152	LED Dimmer with RF Remote Control	29.53
VM154	Fan Timer Module	17.55
VM156	Pocket Audio Generator Module	20.00
VM160	4 Channel RF Remote Control Set	47.50
VM160DT	4 Channel RF Desktop Transmitter	46.28
VM160T	4 Channel RF Replacement transmitter	17.05
VM161	RGB LED Strip Colour controller Module	22.75
VM162	RGB LED Strip Colour dimmer Module	30.86
VM163	Panel Clock Module	25.17
VM164	Mini Dimmer, Push button control	14.78
VM165	0-10V DC Controlled Dimmer	48.95
VM166T	2 Channel Remote with LED	15.12
VM167	Mini USB Interface Module	26.80
VM168	0-10V RGB LED Dimmer Module	34.92
VM169	RGB Power Slave LED Module	25.71
VM179	Proximity Card Reader Module	25.65
VM8090	8 Channel USB Relay Card	58.40

Latest kits & Modules with full tech specs at www.esr.co.uk

ESR ELECTRONIC COMPONENTS

www.esr.co.uk

04/11

Tel: 0191 2514363
Fax: 0191 2522296
sales@esr.co.uk

Station Road
Cullercoats
Tyne & Wear
NE30 4PQ

Prices Exclude Vat @20%.
UK Carriage £2.50 (less than 1kg)
£6.50 greater than 1kg or >£30
Cheques / Postal orders payable to
ESR Electronic Components Ltd.
PLEASE ADD CARRIAGE & VAT TO ALL ORDERS

VOL. 40 No. 6 JUNE 2011

Editorial Offices:
EVERYDAY PRACTICAL ELECTRONICS EDITORIAL Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset, BH21 1UU
Phone: (01202) 880299. **Fax:** (01202) 843233.
Email: enquiries@epemag.wimborne.co.uk
Website: www.epemag.com
See notes on **Readers' Technical Enquiries** below – we regret technical enquiries cannot be answered over the telephone.

Advertisement Offices:
Everyday Practical Electronics Advertisements
113 Lynwood Drive, Merley, Wimborne, Dorset, BH21 1UU
Phone: 01202 880299 **Fax:** 01202 843233
Email: stewart.kearn@wimborne.co.uk

READERS' TECHNICAL ENQUIRIES
Email: techdept@epemag.wimborne.co.uk
We are unable to offer any advice on the use, purchase, repair or modification of commercial equipment or the incorporation or modification of designs published in the magazine. We regret that we cannot provide data or answer queries on articles or projects that are more than five years' old. Letters requiring a personal reply must be accompanied by a stamped self-addressed envelope or a self-addressed envelope and international reply coupons. We are not able to answer technical queries on the phone.

PROJECTS AND CIRCUITS
All reasonable precautions are taken to ensure that the advice and data given to readers is reliable. We cannot, however, guarantee it and we cannot accept legal responsibility for it.
A number of projects and circuits published in EPE employ voltages that can be lethal. You should not build, test, modify or renovate any item of mains-powered equipment unless you fully understand the safety aspects involved and you use an RCD adaptor.

COMPONENT SUPPLIES
We do not supply electronic components or kits for building the projects featured, these can be supplied by advertisers.
We advise readers to check that all parts are still available before commencing any project in a back-dated issue.

ADVERTISEMENTS
Although the proprietors and staff of EVERYDAY PRACTICAL ELECTRONICS take reasonable precautions to protect the interests of readers by ensuring as far as practicable that advertisements are bona fide, the magazine and its publishers cannot give any undertakings in respect of statements or claims made by advertisers, whether these advertisements are printed as part of the magazine, or in inserts.
The Publishers regret that under no circumstances will the magazine accept liability for non-receipt of goods ordered, or for late delivery, or for faults in manufacture.

TRANSMITTERS/BUGS/TELEPHONE EQUIPMENT
We advise readers that certain items of radio transmitting and telephone equipment which may be advertised in our pages cannot be legally used in the UK. Readers should check the law before buying any transmitting or telephone equipment, as a fine, confiscation of equipment and/or imprisonment can result from illegal use or ownership. The laws vary from country to country; readers should check local laws.

EVERYDAY PRACTICAL ELECTRONICS

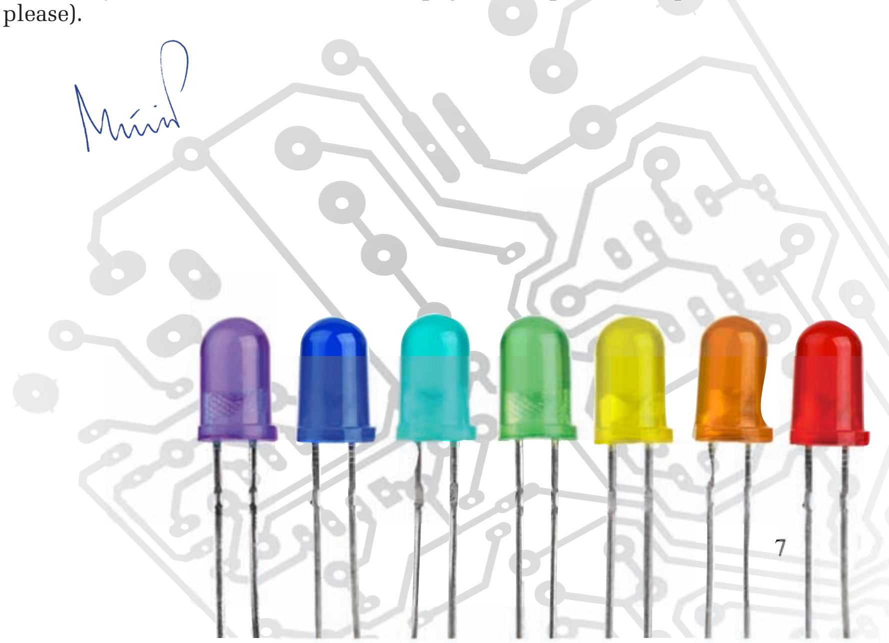
Moaning works

I always enjoy Mark Nelson's *Techno Talk* page, and this month is no exception. Of course, it goes without saying that no *EPE* reader would dream of breaking UK law (or for international readers your local law) by using some of the devices described, but it is fun to read about them. Just for the record, we *do not* endorse any of the products Mark so amusingly describes; we just like to share with you what's out there in the murkier corners of the world of electronics.

Mark provides web links for all the products he discusses, and few would doubt that the Internet has revolutionised communication – as Mark puts it, 'you can't stop progress'. However, there are times when good old-fashioned person-to-person communication just can't be beaten. Twice in April I tried to discuss complaints with my ISP and on-line bank. Both times I felt sure I was conversing with a 'letter-generating customer service bot'. They answered by email in that awful chatty, informal manner that seems to be the default setting for modern complaints departments. I was assured that my letter was valued and appreciated, and someone from a 'team' was not just going to get back to me, but was even eager to do so. Of course nothing happened, so with a heavy heart I faced the purgatory of an endless phone menu to try and get through to a real person.

Eventually, I reached humans in both organisations, and despite a careful explanation of my case I really didn't feel I was getting anywhere… until, that is, I mentioned the 'c' word. The 'c' word, and I will share it with you, seems to work like a cattle prod with customer service departments. Mention it, and all of a sudden you really do have their attention, and in my case I got what I wanted – a refund of excessive bank charges and a reduced monthly fee from my ISP. So, what is this bewitching incantation? It's simply 'close' as in 'my account'. It really does seem to strike fear into the on-line service industries, for whom customer headcount seems to be the be all and end all. Next time you feel you've been ripped off, don't just grumble to yourself. Try the 'c' word and I hope you'll be pleasantly surprised at the results.

We've made a few tweaks to the look and design of *EPE* recently. We think the changes make the magazine look better, and give it a more uniform look. Some of these tweaks are subtle, some more comprehensive – this editorial page is a good example. We hope you approve and, as always, welcome your comments via the letters page (email preferred if possible please).



NEWS

A roundup of the latest Everyday News from the world of electronics

LG takes on the world – in 3D by Barry Fox

The 3D format war – active shutter-versus-passive polarisation – is shaking down into a straight fight between LG and most of the rest of the electronics world.

War was declared at *CES* in Las Vegas in January, when LG attacked active shutter 3D as a 'health risk' because of the high speed flicker caused by rapidly alternating left and right images. This coincided with LG's adoption of FPR, 'film patterned retarder', a cost-cutting method of applying polarising filter strips during screen manufacture.

LG recently unveiled its new European range of 3DTVs in London. Although LG will continue to sell active shutter plasma sets at least for the rest of 2011, all LCD/LED 3D TVs will now use 'passive' FPR; 42, 47 and 55in. LCD/LED models are all being sold under a new name, the 'Cinema 3D' range, to associate with the passive polarisation 3D experience in most cinemas.

In the UK, each set comes with seven pairs of passive glasses, and extras will cost only a couple of pounds, with special deals on 'party packs' of five pairs. Cinema glasses will usually work, says LG with a nudge and a wink.

LG already supplies passive 3D TVs for Sky's 3D pubs, and is cooperating with Sky to offer its 10 million subscribers a cashback offer of up to £400 when they buy a Cinema 3D set.

In comparison

Philips is hedging bets with a range of TVs that includes both active shutter and passive FPR models, but most of the other major manufacturers (eg, Sony, Panasonic) are sticking with active shutter and quietly ignoring LG and passive FPR. The exception is Samsung, LG's bitter rival in Korea, which is now fighting a guerrilla war with LG.

Following CES, Samsung made rebuttals in Korea (*Korea Herald*, 10 March). Yoon Boo-keun, president of Samsung visual display business, said FPR is '1935 technology' and Kim Hyun-suk, vice-president of Samsung's digital media business, argued that FPR could not deliver Full HD, and branded LG 'stupid'.

Samsung privately contacted me and offered comparative demonstrations of FPR and active shutter sets at its labs in the UK, but with the condition that I did not say who had given the demonstration. I declined, saying I needed to identify Samsung as the demonstrator.

Now, following what Samsung brands a misunderstanding, a home cinema magazine (*Home Cinema Choice*, June 2011) has quoted Samsung's European quality assurance manager, David Jung as 'spitting feathers'.

'I am very angry about it as an engineer', Jung is quoted as saying exactly what he had earlier told me privately, 'Other major companies supporting active shutter, such as Panasonic and Sony, are also against this propaganda. The idea that active glasses are harmful is nonsense'.

'The loss of picture clarity from using a polarising filter in the TV panel is more significant. Passive 3D sets cannot deliver full HD 3D. You only get half resolution (1920 x 540) per eye. And if you watch Sky 3D you are getting a quarter HD resolution (960 x 540). It is a huge loss. LG argues that the system is full HD; that 540 lines to each eye adds up to full HD when the brain combines images together. We don't believe this at all.'

Jung also stresses that the viewing angle for passive is more restrictive with a vertical sweet spot of only around 13°. 'If you wall mount a passive TV high and sit low, you won't see any real 3D effect at all!'

To be frank, I found LG's demonstrations of Sky 3D on a passive FPR set perfectly acceptable. And the mass market has always been more concerned with price than quality. So LG has a marketing ace in promising glasses at peanut prices, while active shutters cost around £100 and need batteries that go flat.

BLETCHLEY PARK TRUST LAUNCHES 2011 PROGRAMME OF EVENTS

Bletchley Park has launched its 2011 programme of events on the back of a record-breaking year, with visitor numbers in 2010 up by 20% year-on-year. Added to the large-scale media interest and support from individuals and companies such as HP, 2010 was a very successful year for the one-time code-breaking centre. The 2011 programme of events will again bring out the best of Bletchley Park, with a range of fun-filled and action-packed activities to suit everyone, from families and computer geeks, to photography buffs and 1940s enthusiasts.

This year, Bletchley Park will be combining the annual *Enigma Reunion* (3-4 Sept '11) with an armed forces day, including the cadet field gun completion between army, navy and air cadets. As well as World War Two re-enactors and displays, visitors will have the unique opportunity to mix with and talk to men and women who worked at Bletchley Park during the war when the veterans return to Bletchley Park.

For visitor information, contact Bletchley by phone: 01908 640404, or email them on: **info@bletchleypark.org.uk**, or go to their website: **www.bletchleypark.org.uk**

Mobile phone 'tickets'

One in every eight mobile users worldwide will either have a ticket delivered to their mobile phone or buy a ticket with their phone by 2015, which equates to over 750 million users, according to the latest analysis from Juniper Research. This compares with approximately 1 in 20 now. Ticket delivery will be by SMS, bar codes, mobile web, smartphone apps or NFC (near field communication).

While mobile ticketing users are currently concentrated in a number of early adopting transport schemes in Japan, Central and Eastern Europe and Scandinavia, the report determined that opportunities for mobile ticketing will spread right across the transport, sport, entertainment and events sectors.

The Mobile Ticketing report pinpointed the next two years to 2013 as the key period in which mobile ticketing will transition from a minority experience to become mainstream, as the mobile plays an ever growing role in all aspects of airline travel, rail travel, festivals and cinemas.

Report author Howard Wilcox pointed out: 'Mobile technology is moving the ticket machine into our pockets. Our research demonstrated that mobile ticketing will change the way that many people buy and obtain their regular, every day tickets that are mostly printed at the moment. We foresee strong acceptance, driven not only by airlines but also cinemas and some sports events: bar coded boarding passes are a clear case in point.'

Juniper Research also looked at the amount of mobile data traffic generated by smartphones and tablets, and estimate that it will exceed 14,000 petabytes by 2015, equivalent to 18 billion movie downloads or 3 trillion music tracks.

Pressure on mobile networks, however, will begin to ease, as 63% of traffic, nearly 9000 petabytes, moves across to WiFi and femtocell networks.

Juniper estimate that while data growth over the cellular network will be substantial, it will not be the 'data explosion' that some have anticipated. However, the report notes that despite the implementation of offloading measures, migration of data traffic from fixed to mobile will exacerbate the strains on the cellular network.

Wireless security

Swann Security has released a new digital wireless security camera. The ADW-200 uses secure digital transmission, removing interference and static from other wireless devices such as Bluetooth, web routers and cordless phones.

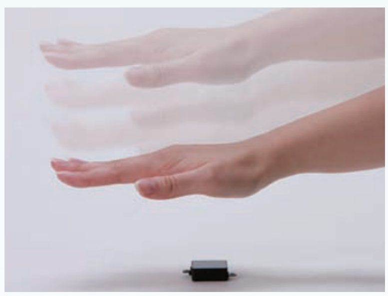
It provides a secure, wireless transmission of up to 50m, and up to 8m night vision. The camera is housed in a robust, weather-resistant metal casing, and the built in microphone means you will hear, as well as see, what is going on. Set up is easy – simply install the camera in the area you want monitored, plug the receiver in your TV, and once set to the same channel, the camera and the receiver will pair up. For further information visit: **www.swann.com**

World's smallest vein sensor

Fujitsu Laboratories has released details of the world's smallest and slimmest contact-free vein authentication sensor. The sensor's tiny size makes it easy to incorporate into PCs and other electronic devices, helping to expand the range of potential applications for palm vein authentication.

Until now, an individual's palm needed to be held motionless over a relatively thick, specialised device in order to capture an image of the palm veins. However, this new sensor incorporates a high-speed image-capture function that can continuously capture up to 20 frames per second, as well as a feature that can instantly pick out the best image for authentication and automatically verify it. Users do not need to hold their hand motionless over the sensor, as before, but can instead perform authentication by simply placing their palm lightly over the sensor.

In recent years, biometric authentication such as palm vein analysis, which can accurately identify individuals based on their biological characteristics, has grown in popularity as a means of personal identification. Fujitsu claim that of all the existing biometric approaches, vein authentication, which reads the invisible pattern of veins in



the palm or finger, offers the benefits of being both highly accurate and resistant to misconduct such as forgery and impersonation. It has been widely adopted as a means of personal identification at financial institutions, and as a computer login and room entrance control method.

Compared to finger veins, palm veins are more numerous and create complex patterns, resulting in a higher volume of data. Consequently, the system's recognition accuracy is extremely high, with a claimed false-negatives rate of 0.01% and a false-positives rate of 0.00008%. Furthermore, the fact that the system uses an individual's thicker veins allows for stable operations over time. Lastly, the system is contact-free, making it easier, quicker and more hygienic to use.

4G Mobile auction

Ofcom has announced plans for the largest ever single auction of additional spectrum for mobile services in the UK, equivalent to three quarters of the mobile spectrum in use today, and 80% more than the 3G auction which took place in 2000.

This spectrum is essential to meet the UK's rapid increase in mobile traffic, fuelled by the growth of smartphones and mobile broadband data services such as video streaming, email, messenger services, mapping services and social networking sites.

The new spectrum will provide much needed capacity for the fourth generation (4G) of mobile technology, set to deliver significantly faster mobile broadband services – approaching today's ADSL home broadband speeds.

The auction will be for two spectrum bands – 800MHz and 2.6GHz. The 800MHz band is part of the digital dividend, which is being freed-up as the UK switches from analogue to digital TV. This spectrum is ideal for widespread mobile coverage. The 2.6GHz band will be used for delivering the higher speeds. These two bands add up to 250MHz of additional mobile spectrum.

by **JOHN CLARKE**

MANY motor speed controller designs use a simple phase-control circuit, which works reasonably well with most universal motors. However, there are some applications where a wider and smoother control range is required.

One shortcoming of such designs is that the maximum speed from the motor when under speed control is significantly reduced. So, for an electric drill that normally runs at say 3000rpm, the maximum speed might be reduced to around 2200rpm. This is inevitable with a controller circuit that effectively half-wave-rectifies the 230V AC mains waveform to give a maximum output voltage of around 160V RMS.

The second drawback of these simple designs has to do with low speed control. While the circuit does allow your drill or other appliance to run at quite low speeds, the result leaves much to be desired. There isn't much torque available and the speed regulation is poor. This means that if you're operating a drill at a low speed, and you put a reasonable load on it, its speed will drop right away or it may stall completely.

Worse still, the motor will tend to 'cog', caused by erratic firing of the triac within the drill's speed controller, so that the motor receives intermittent bursts of power. An electric motor that is cogging badly is virtually useless and the only cure is to increase the speed setting – and this rather defeats the purpose if you want to operate at low speed.

This new Motor Speed Controller overcomes these drawbacks. The design does not use phase-control circuitry, but uses switch-mode power supply techniques to produce an outstanding controller for universal brush-type motors.

Before we go further, we should point out that virtually all mains-powered power tools and appliances use universal motors, which are series wound motors with brushes.

And most power tools will do a better job if they have a speed control. For example, electric drills should be slowed down when using larger drill bits for a cleaner cut.

Similarly, it is useful to be able to slow down routers, jigsaws and even circular saws when cutting some materials, particularly plastics; the same applies to sanding and polishing tools.

Features:

- Full control of motor speed from near zero to maximum
- Speed regulation under load
- Smooth low-speed motor operation
- Rated for universal motors up to 2300W
- Over-current protection and limiting
- Fuse protection
- Rugged earthed diecast case
- Interference suppression filter

Phase control

We will now explain what we mean by phase control, so that we can illustrate the benefits of the new circuit.

High Performance 230VAC 10A Full-Wave Motor Speed Controller

This full-range Motor Speed Controller will give smooth control from near zero to full speed on electric drills, routers, circular saws, lawn edgers, food mixers – in fact, any appliances with universal (brush-type) motors.

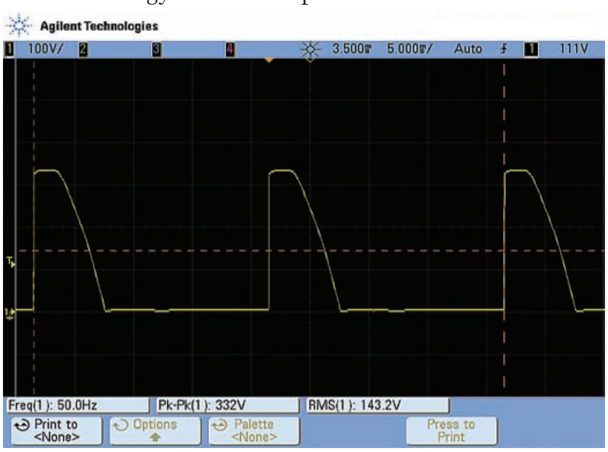
As you know, the mains (AC) voltage closely follows a sinewave – it starts at zero, rises to a peak, falls back to zero, then does the same thing in the opposite direction. This repeats over and over – and does it 50 times each second (50Hz). A motor connected to the mains uses all of the energy it can take from each 'cycle' and it runs at its maximum speed.

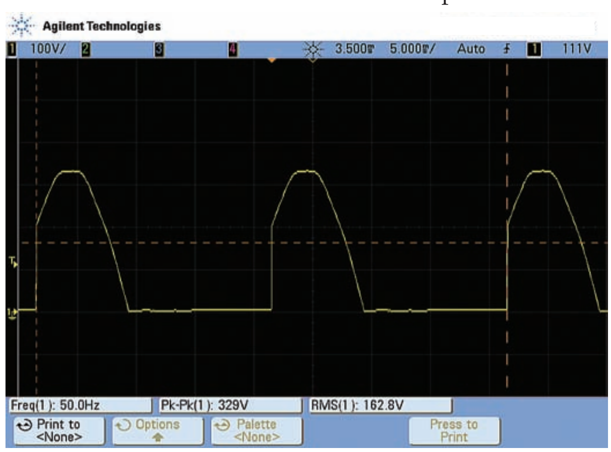
But what if you were able to stop the motor receiving energy until, say, half way through each cycle? Obviously, with less energy available to power it the motor would not run as fast. If you were able to vary the time during each half-cycle when power was applied, you would have a variable speed control. This then is the basis of 'phase control'.

Allow power very early in the cycle and it runs fast. Allow power very late in the cycle and it runs slowly.

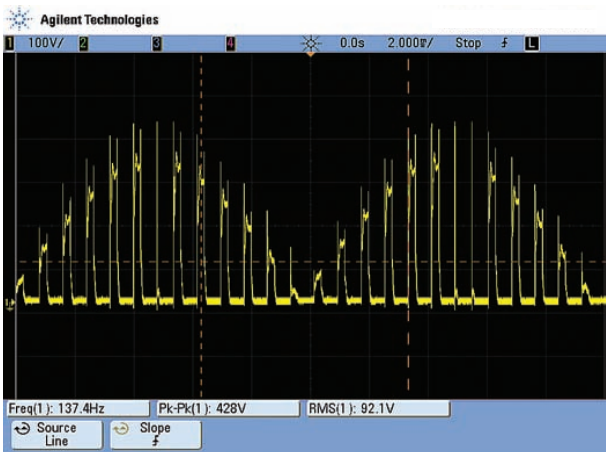
The term 'phase control' comes about because the timing of the trigger pulses is varied with respect to the phase of the mains sinewave.

It doesn't only work with some types of motors – it has also been the basis of incandescent lamp dimmers and





These waveforms illustrate the operation of a typical phase-controlled SCR. In Fig.1 (left) the SCR is triggered fairly late in the positive half-cycle, so the motor voltage is just 143V RMS and it runs at a relatively low speed. Compare this with Fig.2, right, where SCR is triggered earlier in the half-cycle and the RMS value rises to 163V. Hence the motor runs faster.



This series of scope screen grabs show the voltage waveforms applied to the motor at progressively higher speed settings. Fig.3 (above) is the lowest setting with very short pulses from the IBGT delivering just 92V RMS to the motor.

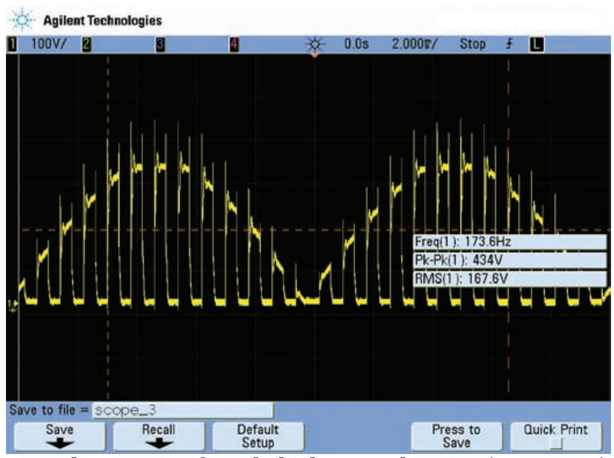


Fig.4 shows a significantly higher speed setting (167V RMS) with the IGBT being switched on with longer pulses. Each time the IGBT turns off it causes a significant voltage spike due to the back-EMF produced by the motor inductance.

even heater controls for many decades. Note, however, that it doesn't work on most forms of fluorescent or compact fluorescent bulbs.

The oscilloscope waveform of Fig.1 shows the chopped waveform from a phase-controlled SCR (silicon-controlled rectifier, or thyristor) circuit when a motor is driven at a slow speed.

Fig. 2 shows the waveform from an SCR speed control at a higher setting. The motor has 163V applied to it, while at the low setting (Fig.1) the motor has 143V applied.

These examples show only the 'positive' half of the mains waveform being used, as is the normal case with a phase-controlled SCR circuit. This automatically limits the amount of power which can be delivered to the motor – one half-cycle is wasted. So this means that in a phase-control circuit, the range of speed control is severely limited at the top end.

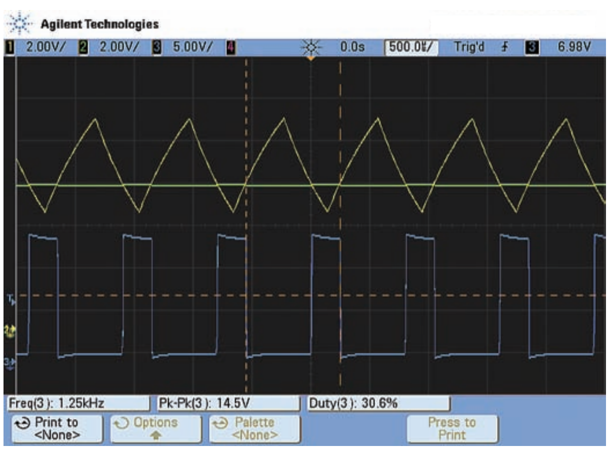


Fig.7: These waveforms show the interaction of the triangle waveform and the speed voltage. The triangle waveform at the top is compared to the speed voltage, the horizontal voltage intersecting the triangle wave. The resulting lower trace is the pulse-width modulation signal from the comparator. The comparator output is fed to the gate driver IC2 and Q2 and Q3, which then drive the IGBT.

For the motor to run at full speed, it would need to be fed with both the positive and negative half-cycles of the 50Hz mains waveform. Normally, this is not possible with an SCR circuit (which is effectively a controlled diode, and therefore only conducts in one direction). While it is possible with a triac, it is difficult to achieve without a complex circuit.

Another big problem with conventional phase-controlled circuits is that the trigger pulse applied to the triac or SCR is very short, and if this corresponds with the instant when the brushes hit an open-circuit portion of the commutator, no current will flow and consequently, the motor will miss out on a whole cycle of the mains waveform. This problem is more critical at low speed settings and is one of the reasons for the 'cogging' behaviour referred to earlier.

Incidentally, the sparks you see when you look into a universal (brush-type) motor are mostly caused by brushes passing through an open-circuit section of the commutator – a typical power drill might have a dozen or more of these, which keep the motor windings separate.

Speed regulation

Most phase-controlled SCR speed control circuits incorporate a form of feedback that is designed to maintain the speed of the motor under load. When the motor is loaded, the back-EMF (electromotive force) produced by the motor drops and the circuit compensates by triggering the SCR earlier in the mains cycle. This helps to drive the motor at the original speed.

In practice, the back-EMF generated by most series motors when the SCR is not conducting is either very low or nonexistent. If there is any back-EMF it is produced too late after the end of each half-cycle to have a worthwhile effect on the circuit triggering in the next half-cycle.

Pulse-width modulation

As we mentioned, this new speed control circuit uses pulse-width modulation (PWM) and a different feedback method for speed regulation that effectively solves the problems discussed above associated with phase control.

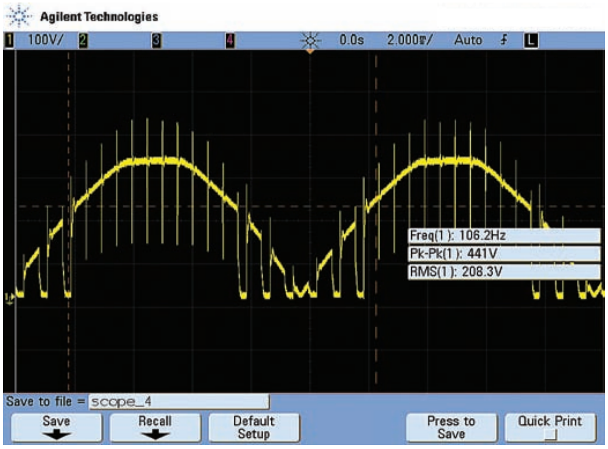


Fig.5 shows an even higher speed setting, with 208V RMS now being delivered to the motor by the IGBT. Motor speed would already be higher than that capable of a phase-controlled circuit and shows how good this circuit is!

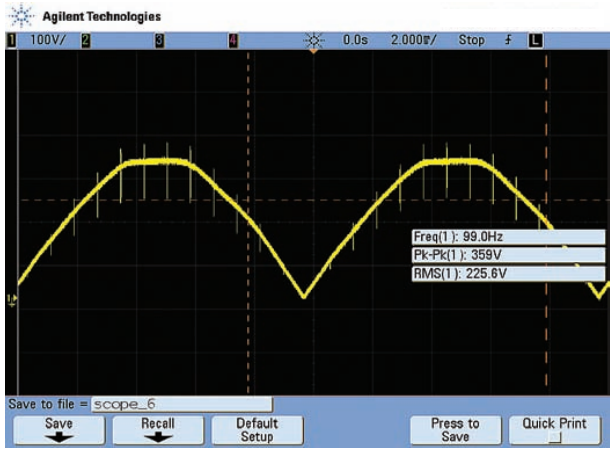


Fig.6: here the IGBT is virtually full on, delivering maximum voltage to the motor. However, the RMS voltage reads lower, due to the fact that the spikes which were present in the earlier waveforms are no longer there to confuse the scope.

Fig.3 and Fig.4 shows the voltage waveforms applied to the motor at high and low speed settings. What happens is that we rectify the mains voltage and then chop it up at a switching rate of about 1.25kHz using a high-voltage IGBT (insulated gate bipolar transistor). For the high-speed setting, the pulses applied to the motor are relatively wide (Fig.3) while at the low speed setting, the pulses are very narrow (Fig.4).

There are 12 pulses during each half-cycle, so the motor receives a more continuous stream of current compared to when driven via phase control. As a result, the motor operates very smoothly over the whole of its speed range.

For speed regulation, the circuit does not rely on back-EMF from the motor. Instead, it monitors the current through the motor and adjusts the pulse width to maintain the motor speed. If the current rises, indicating that the motor is under load, then the pulse width is widened to maintain motor speed.

Block diagram

Fig.8 shows the basic circuit arrangement. The 230V AC input waveform is fed through a filter and full-wave rectified. The resulting positive-going waveform is fed to one side of the motor. The other motor terminal is switched on and off via IGBT Q1.

Switching of Q1 is under the control of comparator IC1b, which compares the speed setting required (as set by VR1) against a triangle waveform generator. If the speed voltage is high relative to the triangle waveform, then the comparator will produce wide pulses at its output. Conversely, a lower speed voltage will reduce the pulse width.

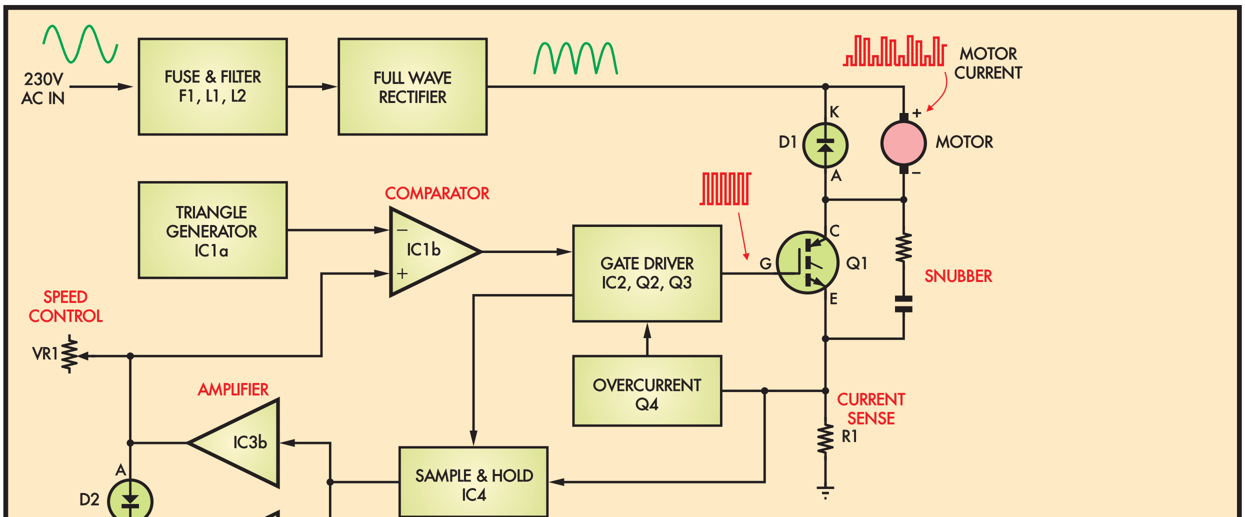
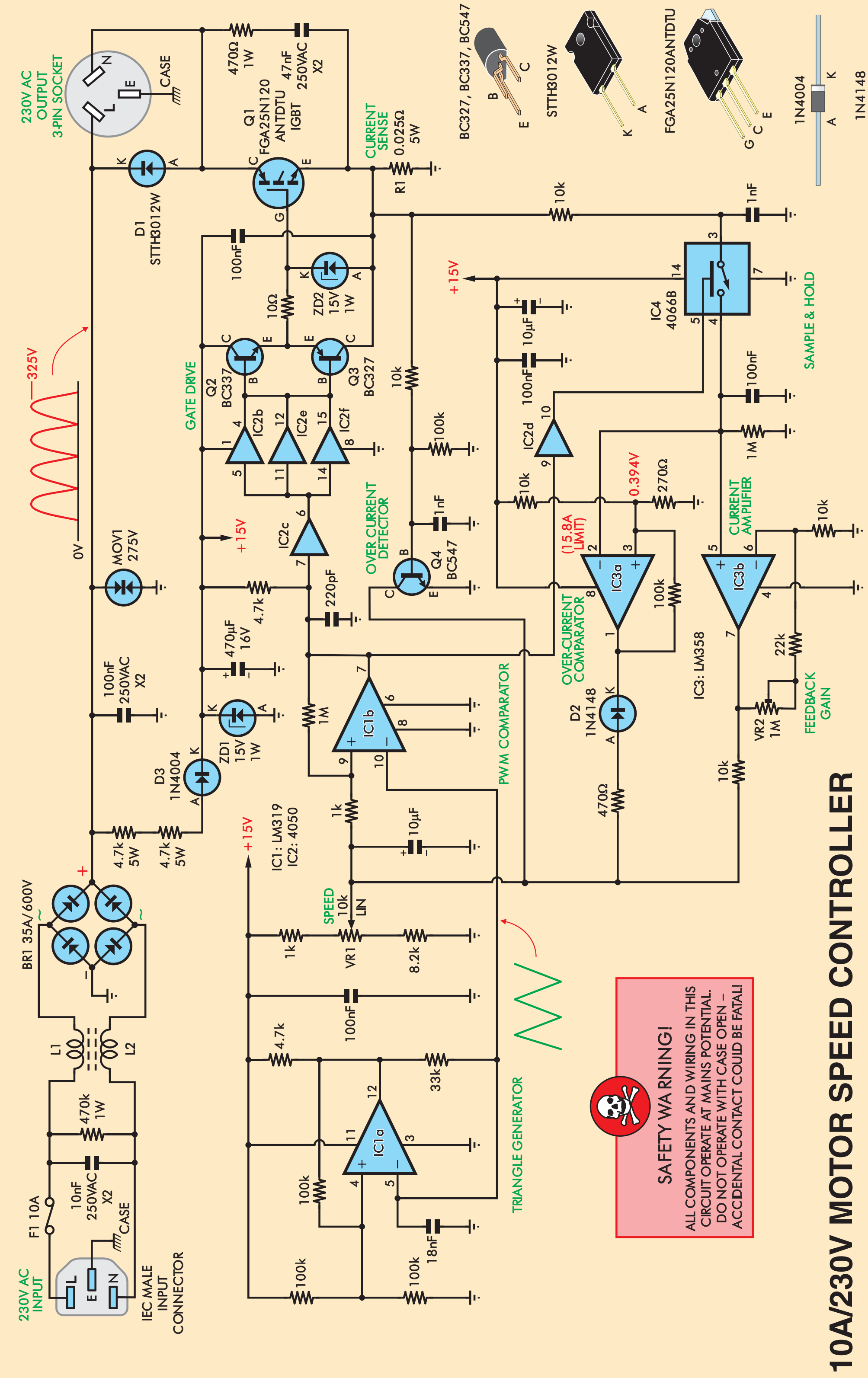


Fig.8: the basic circuit arrangement of the Motor Speed Controller. The 230V AC input is full-wave rectified and fed to one side of the motor, while the other motor terminal is switched on and off via IGBT Q1. A conventional PWM circuit using IC1, IC2 and IC3, controls Q1.



10A/230V MOTOR SPEED CONTROLLER

Fig.9: the circuit uses a 50A 1200V avalanche-protected IGBT (insulated gate bipolar transistor) (Q1) as the switching element to the load. It is switched at 1.2kHz so that there are about 12 on and off cycles for each half-cycle of the 50Hz 230V AC mains supply.

This operation can be seen in the scope waveforms of Fig.7. The triangle waveform at the top is compared to the speed voltage, the horizontal voltage intersecting the triangle wave. The resulting lower trace is the pulse-width-modulation signal from the comparator. The comparator output is fed to the gate driver (IC2 and transistors Q2 and Q3) that then drives the high voltage IGBT (Ql).

Diode D1 is a fast-recovery type to conduct the motor current when Q1 is switched off. The 'snubber' across Q1 prevents excessive voltage excursions across it. Resistor R1 monitors the current flow through the motor when Q1 is on, and the resulting voltage generated is sampled using switch IC4. This sampling occurs whenever Q1 is on.

Excessive current drawn by the motor is detected by transistor Q4, used as an over-current detector to switch off the IGBT gate drive if current exceeds about 48A.

IC3b amplifies the voltage from R1 and applies it to the speed pot. This operates such that an increase in motor current, as the motor is loaded and slows down, leads to an increase in the output from IC3b. This in turn increases the speed setting from VR1, resulting in an increase in the voltage applied to the motor.

IC3a also monitors the voltage produced from R1 via IC4, and compares it against a reference voltage. If the voltage from R1 exceeds the reference threshold, IC3a's output goes low and reduces the speed pot voltage via diode D2. This reduces the voltage applied to the motor and provides current limiting. The current limit is set at 15.8A.

Circuit description

The circuit for the Motor Speed Controller is shown in Fig.9. It comprises four ICs, three low-current transistors,

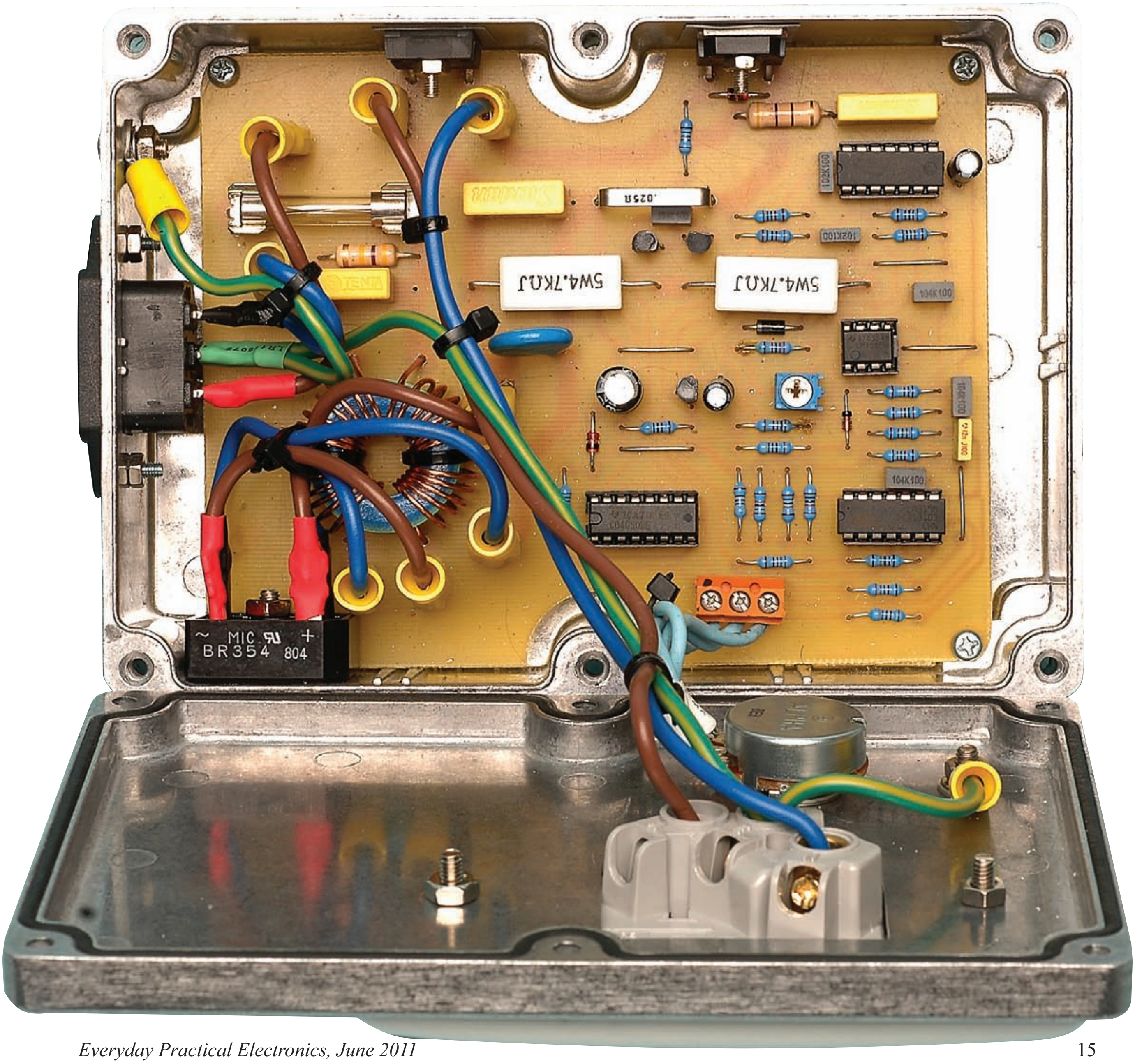
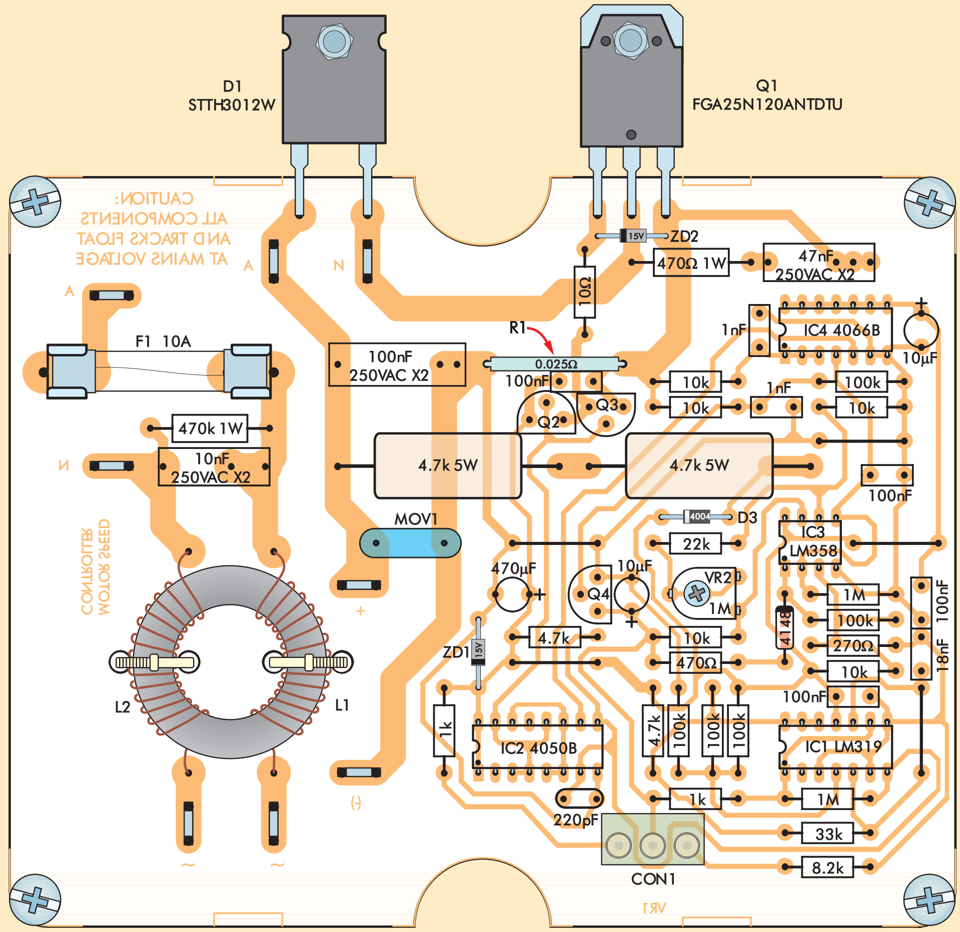


Fig.10: the complete component overlay for the Full-Wave Speed Controller. Be very careful not to mix up the diodes and Zeners – they often look very similar. It's also a good idea to use IC sockets, just in case!



several diodes, resistors and capacitors plus the high voltage IGBT, Q1.

IC1a is a comparator that forms the triangle waveform generator. It is wired as an oscillator, where the 18nF capacitor at pin 5 is charged and discharged via the 33kΩ resistor connected to the output at pin 12. The triangle or ramp waveform across the capacitor has an amplitude of about 5V peak-to-peak.

Comparator IC1b compares the triangle waveform at pin 10 with the speed voltage at pin 9, as set by VR1. VR1 is part of a voltage divider with a 1kΩ resistor connecting to the +15V rail and an 8.2kΩ resistor to 0V. The speed voltage from VR1 is filtered with a 10µF capacitor to prevent any sudden changes in level, and this voltage is monitored by the inverting input (pin 9) of IC1b via a 1kΩ resistor.

The 1MΩ resistor between pin 9 and the pin 7 output provides positive feedback to give a small amount of hysteresis in the comparator action. This is to prevent oscillation of the comparator output when changing levels.

The pin 7 output of IC1b drives buffers IC2c and IC2d. IC2c drives three paralleled buffers, IC2b, IC2e and IC2f. These in turn drive emitter-followers Q2 and Q3 to provide a high-current drive capability to charge and discharge the gate (G) of the high-voltage IGBT Ql. The gate of Q1 is protected from excessive drive voltage by ZD2, a 15V Zener diode. The high voltage can be impressed on the gate via capacitance between the gate and collector when the IGBT switches off.

Several circuit features combine to ensure that the IGBT can safely switch high levels of current through the motor load.

First, there is a snubber network, comprising a 470Ω resistor and 47nF capacitor connected in series across the IGBT's source and drain. Second, there is the fast recovery diode D1. Third, there is a 275V AC metal-oxide varistor (MOV) connected across the output of the bridge rectifier. These measures combine to damp any spike voltages that would otherwise occur every time the IGBT switched off.

Warning!

1) The entire circuit of this motor speed controller floats at 230V AC – and is potentially lethal. Do not build it unless you know exactly what you are doing. DO NOT TOUCH ANY PART OF THE CIRCUIT WHILE IT IS PLUGGED INTO A MAINS OUTLET and do not operate the circuit outside its metal case or without its lid on.

2) This circuit is NOT suitable for induction motors or shaded pole motors used in fans – see text.

Parts List – Full-Wave Universal Motor Speed Controller

1 PC board, code 804, available from the *EPE PCB Service*, size 112mm × 142mm
1 metal diecast case, 171mm × 121mm × 55mm
1 front panel label, 168mm × 118mm
1 powdered-iron core, 28mm × 14mm × 11mm (L1,L2)
1 single switched mains power outlet
1 10A IEC mains lead
1 IEC male chassis connector with mounting holes
1 3-way PC-mount screw terminal block with 5.08mm spacing (CON1)
8 6.35mm PC-mount male spade connectors with 5.08mm pin spacing
8 6.35mm insulated female spade quick connectors with 4-6mm wire diameter entry
2 5.3mm ID insulated quick connect crimp eyelets with 4-6mm wire diameter entry
1 knob
1 16-pin DIP IC socket
2 14-pin DIP IC sockets
1 8-pin DIP IC socket
2 3AG PC-mount fuse clips
1 10A 3AG fast-blow fuse (F1)
2 M4 × 10mm screws (earth connections)
2 M4 × 15mm screws (output socket mounting)
1 M4 × 20mm countersunk screw (BR1 mounting)
5 M4 nuts
2 M4 star washers
2 M3 × 12mm countersunk screws (for IEC Connector)
2 M3 × 15mm screws (for Q1 and D1)
4 M3 nuts
3 3/16-inch × 6mm screws (PC board to case)
4 stick-on rubber feet
8 100mm cable ties
2 TO-3P silicone insulating washers
1 300mm length of blue 10A mains wire
1 300mm length of brown 10A mains wire
1 300mm length of green/yellow 10A mains wire
1 100mm length of 0.8mm tinned copper wire
1 1.1m length of 1mm enamelled copper wire
1 45mm length of black 5mm heatshrink tubing
1 45mm length of red 5mm heatshrink tubing
1 15mm length of green 5mm heatshrink tubing
1 45mm length of white 3mm heatshrink tubing

Semiconductors
1 LM319 dual comparator (IC1)
1 4050 hex CMOS buffers (IC2)
1 LM358 dual op amp (IC3)
1 4066 quad CMOS analogue switch (IC4)
1 BC337 *NPN* transistor (Q2)
1 BC327 *PNP* transistor (Q3)
1 BC547 *NPN* transistor (Q4)
1 FGA25N120ANTDTU *NPN* 50A 1200V TO-3P IGBT (Q1) (Farnell cat 149-8965)
1 STTH3012W 30A 1200V TO-247 ultrafast recovery diode (D1) (STMicroelectronics)
1 1N4148 signal diode (D2)
1 1N4004 1A 400V diode (D3)
2 15V 1W Zener diodes (ZD1,ZD2)
1 35A 600V bridge rectifier (BR1)
1 S14K275 275V AC metal-oxide varistor (MOV1)

Capacitors
1 470µF 16VW PC electrolytic
2 10µF 16VW PC electrolytic
1 100nF 250VAC X2 class MKT polyester
4 100nF 63V MKT polyester
1 47nF 250VAC X2 class MKT polyester
1 18nF 63V MKT polyester
1 10nF 250VAC X2 class MKT polyester
2 1nF 63V MKT polyester
1 220pF ceramic

Resistors (0.25W, 1%)

2 1MΩ	1 470kΩ 1W	5 100kΩ
1 33kΩ	1 22kΩ	5 10kΩ
1 8.2kΩ	2 4.7kΩ	2 4.7kΩ 5W
2 1kΩ	1 470Ω 1W	1 470Ω
1 270Ω	1 10Ω	

1 low-ohm shunt resistor 0.025Ω, 1%, 5W (OAR5 – R025F1) (TT Electronics)
1 10kΩ 25mm linear potentiometer (VR1)
1 1MΩ horizontal trimpot (VR2)

Current monitoring

Sense resistor R1 is used to monitor the current flow through the motor and IGBT Q1. Transistor Q4 directly monitors the current via a voltage divider comprising two 10kΩ resistors in series. At roughly 48A there is about 1.2V across R1, and the base of Q4 is at 0.6V. The transistor conducts and pulls the IC1b comparator output low to disconnect drive to the IGBT. Thus, Q4 provides for transient current limiting.

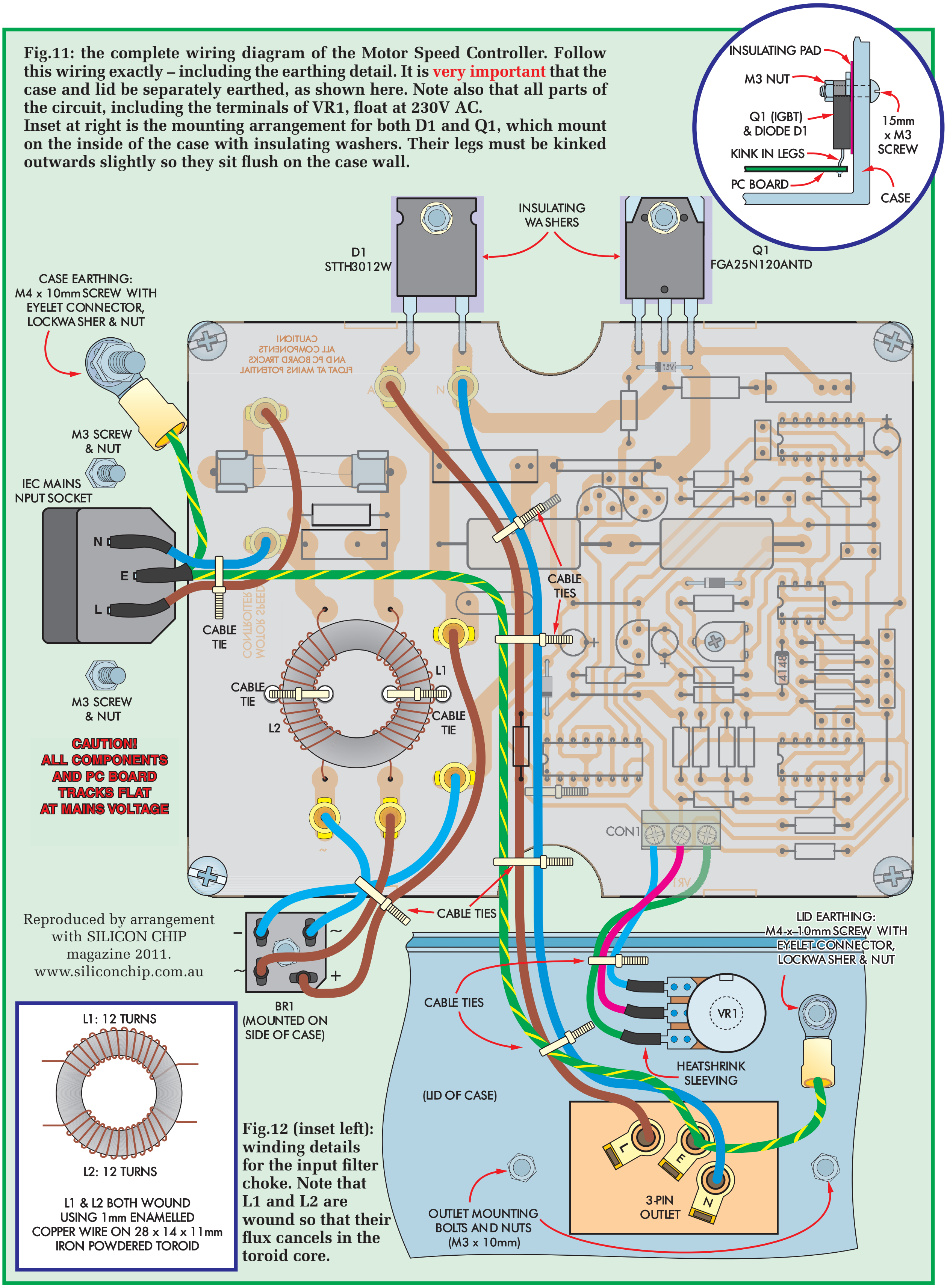
Voltage developed across R1 is also fed through a low-pass filter consisting of a 10kΩ resistor and 1nF capacitor to one side of IC4, a 4066 analogue switch. This is the sample-and-hold circuit, and IC4 is switched on to sample the voltage across R1 each time the IGBT is switched on. IC4's gate signal comes from comparator IC1b and is buffered by IC2d. The sampled signal from R1 is stored using the 100nF capacitor and discharged over a 100ms period with a 1MΩ resistor.

The sampled voltage from IC4 is fed to two op amps, IC3a and IC3b. IC3b amplifies the voltage by about 100 when VR1 is set to maximum and 3.2 when set to minimum. IC3b acts to vary the DC level fed to comparator IC1b from VR1, and thereby compensates for speed variations in the motor.

IC3a acts as a comparator, comparing the sampled voltage from R1 with a 394mV reference voltage at its pin 3. If the current through R1 rises above 15.76A, the voltage across the resistor equals the 394mV reference and the output of IC3a goes low and pulls pin 9 of IC1b low via diode D2 and a 470Ω resistor. This has the effect of greatly reducing the motor drive voltage, and so it limits the current.

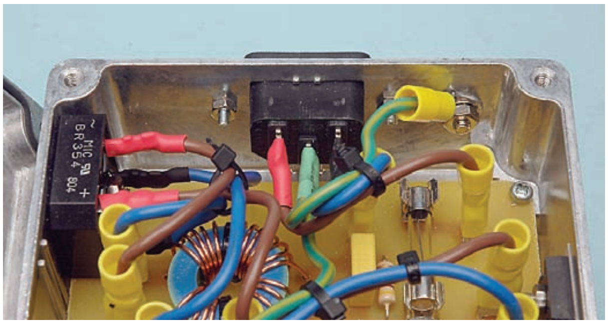
Power for the circuit is derived directly from the 230V AC mains. Fuse F1 protects against shorts, while the 10nF capacitor, in conjunction with L1 and L2, prevents switching artefacts from the IGBT and motor being radiated back to the mains wiring.

Fig.11: the complete wiring diagram of the Motor Speed Controller. Follow this wiring exactly – including the earthing detail. It is **very important** that the case and lid be separately earthed, as shown here. Note also that all parts of the circuit, including the terminals of VR1, float at 230V AC.
Inset at right is the mounting arrangement for both D1 and Q1, which mount on the inside of the case with insulating washers. Their legs must be kinked outwards slightly so they sit flush on the case wall.

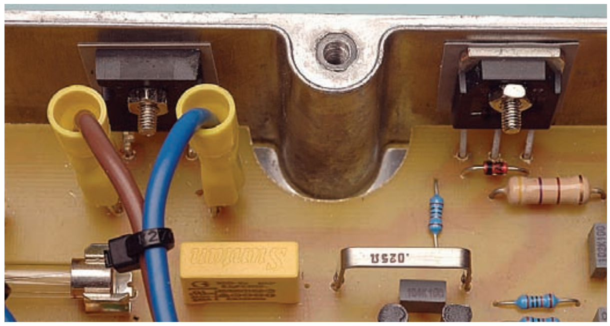


Reproduced by arrangement with SILICON CHIP magazine 2011. www.siliconchip.com.au

Fig.12 (inset left): winding details for the input filter choke. Note that L1 and L2 are wound so that their flux cancels in the toroid core.



A close-up photo of the input (IEC socket) wiring, fuse, choke and bridge rectifier. All mains leads are terminated in quick-connect terminals.



Similarly, a close-up of the IGBT (right) and fast recovery diode (left). These devices do not require an insulating bush, but definitely do need an insulating washer, as seen here.

BR1 is a bridge rectifier with a 600V 35A rating. The bridge provides the circuit with the positive full-wave rectified mains voltage, and this is lightly filtered using a 100nF 250V AC (X2) capacitor. Power for the low voltage circuitry is sourced from two series 4.7kΩ 5W resistors, diode D3 and the 15V Zener diode ZD1. A 470µF capacitor across the 15V Zener smooths the DC, while diode D3 prevents the capacitor from discharging when the mains voltage falls to below 15V every half cycle. The result is a regulated 15V supply.

Construction

The Motor Speed Controller is constructed on a PC board measuring 112mm × 142mm. This single-sided board is available from the *EPE PCB Service*, code 804. It is housed in a diecast case, measuring 171mm × 121mm × 55mm. The PC board has cut-outs to match the shape of the specified case.

Begin construction by checking the PC board. There should not be any shorts or breaks between tracks. If there are any problems, repair these as necessary. Similarly, if the cutouts in the sides of the PC board have not been shaped, they should be cut and filed before any components are assembled.

A large semicircular cutout is required on both of the long sides of the board. Also, you will need to round off the corners of the board. Make sure the PC board fits into the case before starting assembly.

Follow the component overlay diagram shown in Fig.10, and commence by inserting and soldering in the five wire links and then the resistors, using the accompanying table for the colour codes. The two 5W resistors should be inserted so that they stand a millimetre above the PC board to allow cooling. When the Motor Speed Controller is operating, each resistor will be dissipating about 2.7W so they will run quite hot to the touch.

When inserting diode D2 and D3 and Zener diodes ZD1 and ZD2, take care with their orientation and be sure to place each type in its correct place. Diode D1 is installed later.

We used IC sockets for the ICs. Be sure to install these the correct way around, with the notch facing the direction shown on the overlay diagram. Transistors Q2 to Q4 can now be inserted, again taking care to place each in its correct position.

Capacitors are installed next. The accompanying capacitor table shows the various codes that are used to indicate the capacitance values of the polyester capacitors. The electrolytic capacitors must be oriented with the correct polarity.

Filter choke windings L1 and L2 are wound on a single powdered-iron toroidal core, as shown in Fig.12. Each winding is wound using 12 turns of 1mm enamelled copper wire, with the shown direction.

While the exact number of turns is not critical, it is important that both windings have the same number of turns and that they are wound in the directions as shown. The wire ends can be soldered to the PC board after they have been stripped of insulation using some fine abrasive paper, or a sharp hobby knife. After soldering, secure the toroid to the PC board with two plastic cable ties. These wrap around the core and through holes in the PC board. (It is important not to secure the toroid with lengths of wire; these could make a shorted turn around the toroid).

Fuse F1 is mounted in fuse clips that are installed into the PC board as shown. Clip the fuse into the clips first (lugs to the outer ends of the fuse) then insert them into the PC

Capacitor Codes

Value	µF value	IEC code	EIA code
100nF	0.1µF	100n	104
47nF	0.047µF	47n	473
18nF	0.018µF	18n	183
10nF	0.01µF	10n	103
1nF	0.001µF	1n0	102
220pF	NA	220p	221

Resistor Colour Codes

No.	Value	4-Band Code(1%)	5-Band Code (1%)
2	1MΩ	brown black green brown	brown black black yellow brown
1	470kΩ	yellow violet yellow brown	yellow violet black orange brown
5	100kΩ	brown black yellow brown	brown black black orange brown
1	33kΩ	orange orange orange brown	orange orange black red brown
1	22kΩ	red red orange brown	red red black red brown
5	10kΩ	brown black orange brown	brown black black red brown
1	8.2kΩ	grey red red brown	grey red black brown brown
2	4.7kΩ	yellow violet red brown	yellow violet black brown brown
2	1kΩ	brown black red brown	brown black black brown brown
2	470Ω	yellow violet brown brown	yellow violet black black brown
1	270Ω	red violet brown brown	red violet black black brown
1	10Ω	brown black black brown	brown black black gold brown

What motors can be controlled?

We've noted elsewhere in this article that the vast majority of power tools and appliances use so-called universal motors. These are series wound motors with brushes. But how do you make sure that your power tool or appliance is a universal motor and not an induction motor? As we also said before, **induction motors must not be used with this speed controller**.

One clue is that most universal motors are quite noisy compared to induction motors. However, this is only a guide – it's certainly not foolproof.

In many power tools you can easily identify that the motor has brushes and a commutator – you see sparking from the brushes and that settles the matter. But if you can't see the brushes, you can also get a clue from the nameplate or the instruction booklet.

OK, so how do you identify an induction motor? Most induction motors used in domestic appliances will be 2-pole or 4-pole and always operate at a fixed speed which is typically 2850rpm for a 2-pole or 1440rpm for a 4-pole unit. The speed will be on the nameplate. Bench grinders typically use 2-pole induction motors.

Note that this speed controller must NOT be used with power tools, etc, which already have a speed controller built into the trigger.

One final point: if you are using this controller with a high power tool such as a large circular saw or 2HP router, it will not give the same kick when starting.

Because of the current limiting, the motor will take a few seconds to come up to full speed. Normally though, if you want to use the appliance at full speed, it is better not to use the Speed Controller at all.

board and solder in position – this (hopefully) ensures that you don't solder them in the wrong way around.

Solder in the eight 6.4mm PC-mount spade connectors to the PC board for the mains wiring connections, along with the 3-way screw terminal connector for the potentiometer connecting wires.

D1 and Q1 are the last components to be soldered to the PC board. Solder them in so their metal flanges are towards the edge of the PC board and their full-length leads extend about 1mm below the PC board.

All that is left are bridge BR1, diode D1 and IGBT Q1, all of which mount on the inside walls of the case when the PC board is in place.

Mounting the hardware

First of all, mark out the hole position for the IEC connector and earth screw in the end-wall of the case. The IEC connector mounts in the horizontal centre, about 6mm down from the top.

As you can see in our photographs, about 1mm of the top of the end-wall channel is left when the hole is made.

Another view of the completed motor speed controller, very close to same size. The front panel artwork is given in Fig.13. The lid cutout for the switched output socket will, of course, depend on the type used.

The IEC hole is made by drilling a series of small holes around the perimeter of the desired shape, knocking out the piece and filing to shape.

Insert the PC board into the case and mark the mounting hole positions for diode D1, IGBT Q1 and bridge rectifier BR1. Note that the leads for D1 and Q1 must be kinked outward slightly so that the metal flange of each device is parallel to and in contact with the side of the case.

Drill out the holes for these three components. Holes are also required in the lid for the output socket, VR1 and the earth terminal. All holes must be deburred on the inside of the case with a countersinking tool or larger drill to round off the sharp edge of the hole, and in the case of D1 and Ql, prevent punch-through of the insulating washers.

Attach the PC board to the case with the 3/16-inch screws. Note that we do not use a screw in the corner where BR1 mounts. BR1 effectively holds the PC board in place here. Secure D1 and Q1 to the case with a screw, nut and insulating washer. The arrangement for this is shown in the inset diagram in Fig.11.

After mounting D1 and Q1, check that the metal tabs of the devices are isolated from the case by measuring the resistance with a multimeter. The meter should show a very high resistance measurement between the case and any of the diode and IGBT leads.

The complete wiring diagram is shown in Fig.11. The earthing details of the case are most important, since the IGBT, fast recovery diode D1 and potentiometer, VR1, are all at mains potential yet are attached to the case. If the insulating washers or the insulation of the potentiometer were to break down, the case would be live (ie, at 230V AC) if it was not properly earthed.

For the same reason, the case lid must also be separately earthed, also as shown in Fig.11.

The bridge rectifier (BR1) is secured to the case with a 4mm screw and nut. It does not require an insulating washer between its body and the case wall.

All mains wiring must be done using 10A mains-rated (250V) wire. Wiring for the potentiometer must also be mains rated, but it does not need to be 10A rated. The IEC connector must be wired using the correct wire colours with brown for the live, blue for the neutral and green/yellow striped wire for the earth. Use quick-connectors for the mains wiring connection to the PC board connectors. Wires to the IEC connector need to be insulated with heatshrink tubing covering all exposed metal.

Troubleshooting the Motor Speed Controller

If the speed controller does not work when you apply power, it's time to do some troubleshooting.

First, a reminder: **all of the circuit is connected to the 230V AC mains supply and is potentially lethal**. This includes the tabs of D1 and Q1, the terminals of potentiometer VR1 – in fact, all other parts. Do not touch any part of the circuit when it is plugged into a mains outlet. **Always remove the plug from the mains outlet before touching or working on any part of the circuit.**

If the live circuit **must** be worked on, it must be operated via a 1:1 mains isolation transformer. We're only saying that because it is safer, but we'd still prefer you didn't do it.

Before going any further, give you PC board another thorough check (using a magnifying glass?). Kit suppliers tell us that at least 99% of problems are due to wrong or swapped components, right components in the wrong way around and, of course, the 'biggie': poor soldering (or even completely missed solder joints).

If you are 110% sure your Speed Controller isn't suffering from any of these maladies, it's time to get more technical!

Fortunately, there **is** a safe way to check most of the circuit and that is to operate it from a low voltage (12V) DC supply.

Naturally, before you remove the lid you would have already disconnected the 230V mains lead **(don't just turn it off, unplug it!)**. The supply is connected with the positive connecting to the anode of diode D3 and the negative connecting to the anode of ZD1 (the anodes are the ends opposite the striped end on the diode body).

Before you connect the supply, measure it to make sure it is not exceeding **14V** – if it does, you're liable to blow up the 15V Zener diode.

With power applied, a multimeter connected with the negative lead to the negative supply can be used to test voltages. First, check that there is 11.4V on pin 1 of IC2 and pin 11 of IC1. IC3 should have 11.4V on pin 8. Similarly, pin 14 of IC4 should also have 11.4V.

The voltage on the wiper of VR1 should be adjustable from 4.86V to 10.79V or similar by rotating the potentiometer to its full extremes. The same voltage range should be seen at pin 9 of IC1b.

Pin 7 of IC3a should be close to 0V. Pin 1 of IC3b should be at about 9V or more.

With the meter still set to read DC volts, the triangle wave can be measured and should provide approximately a half supply reading, in this case about 5V. If your meter can read a AC volts at 1kHz, then the meter can be set to read ACV. The reading will be around 1.5ACV.

Similarly, when the multimeter is set to read DC volts the pulse-width drive can be checked. On the output of IC1a at pin 7, the DC volts should be adjustable from 0V to close to 11V when VR1 is altered from minimum to maximum. The same voltage range should be available at the pin 4, pin 12 and pin 15 output of IC2. A slightly lower voltage range will be available on the gate of Q1.

If the gate voltage remains at 0V, then suspect a damaged IGBT, a shorted ZD2 or open-circuit 10Ω resistor.

Measuring the resistance between IGBT pins is a simple way to check it. If there is a short circuit between collector and emitter, or if the gate is shorted to the emitter, then the IGBT is faulty.

Diode (D1) operation can be checked using the diode test on your multimeter. In any case, there should not be a short circuit measured between anode and cathode.

Be sure to remove the 12V supply and replace the lid before reconnecting to the mains.

Incidentally, **do not try to monitor the waveforms with an oscilloscope unless you know exactly what you are doing.** Ideally, it needs to be a scope with true differential inputs or a mains isolation transformer. The waveforms in Fig.7 can only be measured using a low-voltage DC supply, as detailed above.

You must not connect the earth terminal of a scope probe to any part of the circuit. If you do, you are likely to cause severe damage to the circuit and possibly to the scope as well!

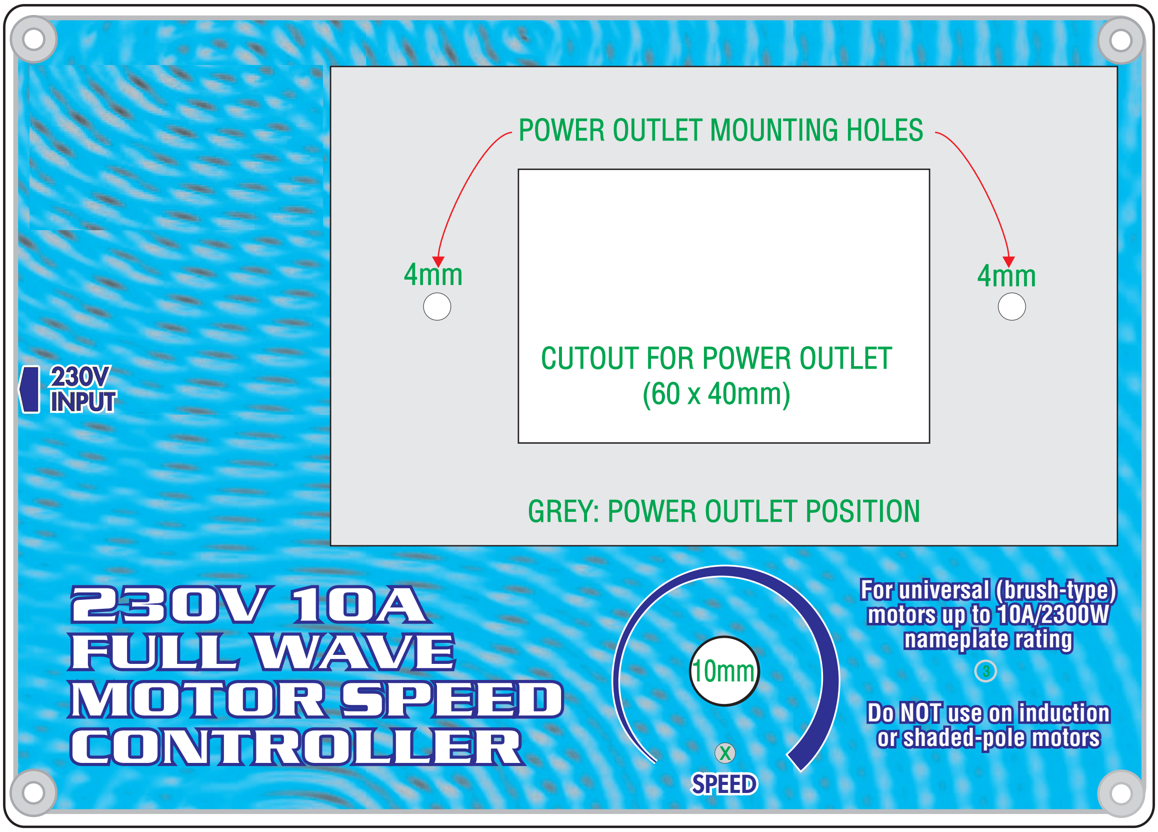


Fig.13 : same-size artwork for the front panel. A photocopy of this can also be used as a drilling/cutting template.

x: 3mm pot locating hole drilled from lid underside – does not need to go all the way through lid.

For the earthing, solder two earth wires from the IEC connector, with one terminating to the earth eyelet and the other running to the power outlet earth terminal. Another green/yellow earth wire runs between the earth connection on the power outlet and the earth eyelet on the lid. The earth eyelets are secured with M4 screws, a star washer and nut.

Wire up the potentiometer, again using 250V AC-rated wire. The reason for this voltage rating is to ensure that in the worst-case scenario and a mains-voltage-carrying wire lets go inside the case (eg, it unsolders due to heat), a bare end contact with one of the pot wires will not allow mains to 'punch through' lesser-rated wire insulation.

Finally, hold the wiring in place using cable ties as shown – also to minimise the possibility of loose wires contacting something they shouldn't.

Note that the live and neutral wires running to the output socket should not be allowed to lie near to the potentiometer wiring. Instead, have these wires lie on the Q1 side of R1 when the lid is closed. Failure to observe this wiring arrangement may cause the controller to power the motor with sudden bursts of speed.

This is to minimise the possibility of the high voltage switching signal on the neutral wire being induced into the potentiometer wiring.

Testing

Before you power up the circuit, insert the ICs into their respective sockets, taking care with their orientation. Set trimpot VR2 to its mid-position – this setting should give good performance with most motors.

Now, check all of your wiring very carefully against the overlay and wiring diagram. Also check that the case and lid are connected to the earth pin of the power socket.

If you are satisfied that all is as it should be, screw the lid onto the case.

Do not be tempted to operate the Motor Speed Controller without the lid in place AND screwed in position – it's not worth the risk.

The easiest way to test the circuit operation is to connect a load such as an electric drill. Apply power and check that you can vary the drill speed with VR1. Some motors may require adjustment of VR2 for best speed regulation, which must be done on a trial-and-error basis. Disconnect power from the mains wall outlet (or unplug the IEC connector) before removing the lid, adjust VR2 very slightly and replace the lid.

In practice, if VR2 is adjusted too far clockwise, the motor will tend to be overcompensated when loaded and will actually speed up. It may even hunt back and forth between a fast and slow speed. If this happens, readjust VR2 anticlockwise for best results.

If you are using a drill, for example, at fairly low speed, the motor should not slow down by much as you put a reasonable load on it.

At the risk of sounding repetitive, remove the plug from the mains outlet before making any changes to VR2 and replace the lid before reconnecting power. ***EPE***


mikroC
PRO for PIC
dsPIC
PIC32
everywhere
If you need more power, just switch over from PIC or dsPIC to PIC32 easily. We have been carefully planing backward compatibility for over 500 of our library functions, so you will be able to literally copy-paste your existing codes and build them with just a few adjustments.
MikroElektronika
DEVELOPMENT TOOLS | COMPILERS | BOOKS
www.mikroe.com

By JIM ROWE

Precision 10V DC reference for checking DMMs

Have you ever checked the calibration of your digital multimeter? Yeah, we know – you haven't because there is no easy (read cheap) way of doing it. But now you can with this precision DC voltage reference that can be built in a few hours. Without any need for adjustment, it will provide you with a 10.000V DC source accurate to within ±3mV, ie, an accuracy of ±0.03%.

MOST of us don't ever get our DMMs calibrated, though they do drift out of calibration over years of use. If you are using them in your occupation, they should be checked every year or so – otherwise, how can you trust the readings?

But it can cost quite a bit to send a DMM away to a standards lab for calibration – more than many DMMs are worth. So generally, we either hope for the best or simply buy a new DMM if we suspect that our existing meter has drifted too far out of calibration.

Voltage source

Back in the 1970s, when DMMs first became available, the only practical source of an accurately known DC voltage was the Weston cell, a wet chemical 'primary cell' that had been developed in 1893 and had become the international standard for EMF/voltage in 1911 (see panel). It produced an accurate 1.0183V reference, which could be used to calibrate DMMs and other instruments.

Unfortunately, Weston cells were fairly expensive and few people had direct access to one for meter calibration. As a result, most people tended to use a reasonably fresh mercury cell as a 'poor man's' voltage reference. Fresh mercury cells have a terminal voltage very close to 1.3566V at 20°C, and this falls slowly to about 1.3524V after a year or so. Silver oxide cells can be used for the same purpose, having a stable terminal voltage very close to 1.55V.

Of course, batteries of any kind have a tendency to obey Murphy's Law and usually turn out to have quietly expired before you need them. And

although mercury and silver oxide cells have quite a long life, especially if you use them purely as a voltage reference, they certainly aren't immune to this problem. Therefore, batteries make a pretty flaky voltage reference, at best.

Fortunately, in the 1980s, semiconductor makers developed a relatively low-cost source of stable and accurately predictable DC voltage: the precision monolithic voltage reference (PMVR). This is a kind of up-market relative of the familiar 3-terminal voltage regulator IC. Like 3-terminal regulators, PMVRs produce a regulated DC output voltage when they are fed with unregulated DC power.

The Analog Devices AD588 device we're using in this new voltage reference project incorporates a number of recent advances in PMVR technology. These include an ion-implanted 'buried' Zener reference diode, plus high-stability thin-film resistors on the wafer, which are laser trimmed to minimise drift and provide high initial accuracy.

It also incorporates highly stable on-chip op amps which are configured to allow Kelvin connections to the load and/or external current boosters, for driving long lines or high current loads.

Block diagram

You can see what's inside the AD588 in the block diagram of Fig.1. The voltage reference cell is at upper left, consisting of the 'buried' Zener (6.5V) and its current source, together with op amp A1. All the resistors (R1 to R6) are high-stability thin-film resistors, laser trimmed to allow the gain of A1 to be set to a high degree of precision – so the cell's basic output voltage (between pins V_{HI} and V_{LO}) is initially set to 10.000V ±3mV (for the AD588JQ/AQ version we use here), without any external adjustment.

Temperature compensation inside the cell also gives the basic voltage reference a very low temperature drift coefficient: typically ±2ppm/°C. In addition, resistors R4 and R5 can be configured to provide a very accurate 'centre tap' for this voltage, allowing the chip to be used as a precise source of ±5.000V ±1.5mV.

Although this basic untrimmed initial accuracy of the AD588 (10.000V ±0.03%) is good enough for calibrating the majority of low-cost DMMs, the chip can also be trimmed very easily

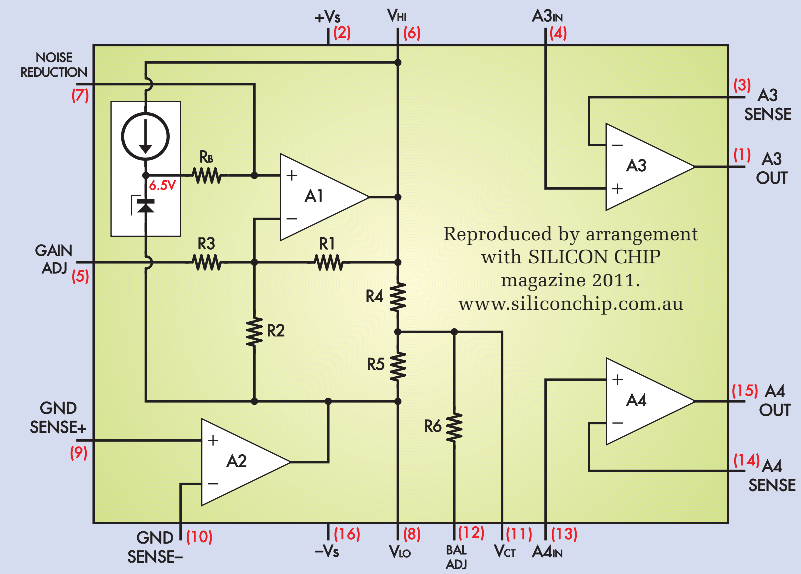


Fig.1: block diagram of the AD588 voltage reference. It contains four op amps (A1-A4) plus a 'buried' Zener and its current source to provide the voltage reference cell.

Specifications

Output voltage: 10.000V DC

Sensing: internal or remote sensing to compensate for output cable voltage drop

Basic accuracy: ±0.03% (±3mV) without adjustment, ±0.002% after optional trim adjustment and calibration

Long term drift: <15ppm per 1000 hours, mostly in first year of operation

Temperature coefficient: 3ppm/°C between –25°C and +85°C

Maximum output current: 10mA

Noise on output: less than 6mV RMS

Load regulation: less than ±50µV/mA for loads up to 10mA

Supply line regulation: less than 200µV/V

Power supply: 12V AC, current drain <60mA

to improve its accuracy by a factor of greater than 10 times – ie, to an accuracy around ±0.002%.

This is done by connecting the GAIN ADJ pin to a 100kΩ trimpot, connected between the V_{HI} and V_{LO} terminals. The pot allows the gain of A1 to be adjusted for a very small output voltage range (approximately -3.5mV to +7.5mV) without any adverse effect on temperature stability. Of course, in order to take advantage of this trimming feature, you must have access to an even higher precision voltage reference, to compare it with.

Op amp A2 is used to allow accurate 'ground sensing', ensuring that the external system ground is accurately held at the same potential as V_{LO}. Op amps A3 and A4, which are internally compensated, act as output buffers for the V_{HI} and V_{LO} voltages, as well as providing for a full Kelvin (ie, remote sensing) output connection.

Circuit details

As you can see from the full circuit diagram in Fig.2, there's not a great deal in our new precision voltage reference apart from the all-important AD588 chip (IC1) – the heart of the project.

All that we need to do in the rest of the circuit is provide it with a moderately regulated and filtered power

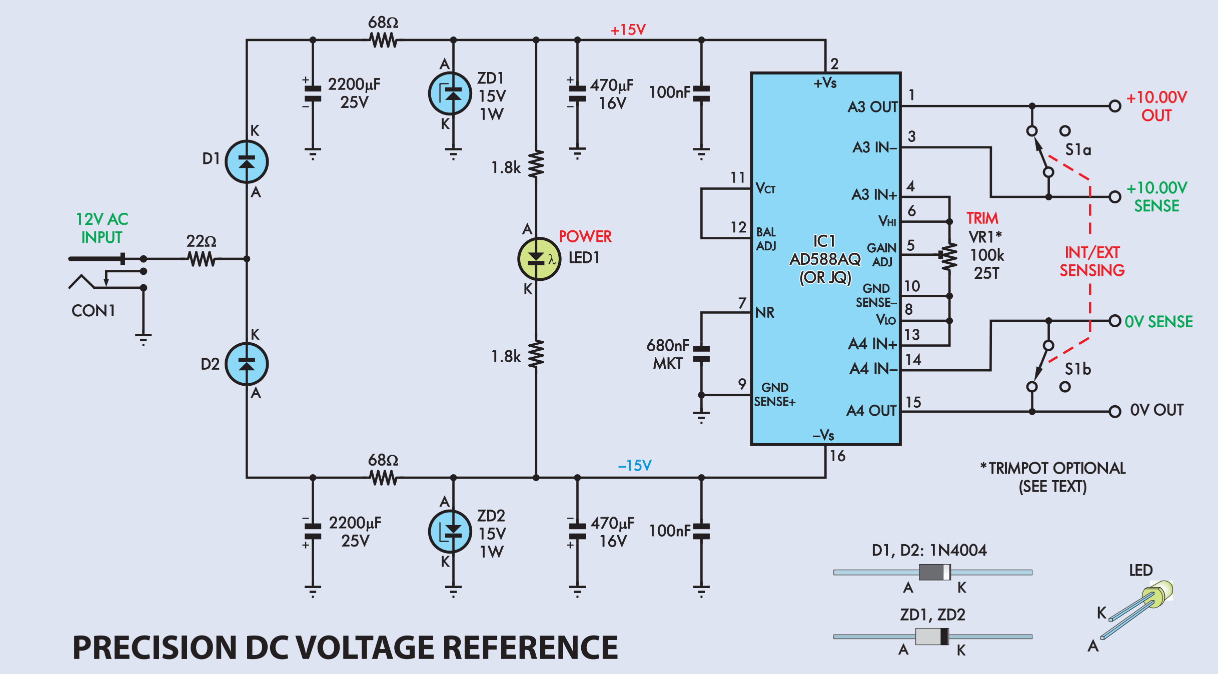


Fig.2: the circuit uses the AD588 precision voltage reference (IC1) and not much else. Diodes D1 and D2 function as half-wave rectifiers and feed Zener diodes ZD1 and ZD2 to provide ±15V rails for the IC.

source of ±15V, and also make its buffered output voltage available, either at the main local terminals, or at the end of a cable connected to a remote load.

The power supply configuration is quite straightforward, and uses a half-wave rectifier circuit to produce each DC supply rail from a 12V AC input (which can be a 12V 500mA AC plugpack). Diodes D1 and D2 form the rectifiers, with filtering provided by two 2200µF electrolytic capacitors. Zener diodes ZD1 and ZD2 (both 15V types) then provide moderate regulation for the two supply rails, in conjunction with the two 68Ω series resistors.

A small amount of additional filtering is provided by two 470µF electrolytics, together with 100nF bypass capacitors at the supply pins for IC1. Note that power indicator LED1 is connected directly between the two supply rails, in series with two 1.8kΩ current-limiting resistors.

The connections for IC1 itself are fairly easy to follow. The 680nF capacitor connected to ground from the NR pin (7) is included to provide additional low-pass filtering of any noise generated by the AD588's buried Zener. It works in conjunction with series resistor RB, as shown in Fig.1.

Op amp A3 inside IC1 is used as the positive voltage output buffer, with its non-inverting input (pin 4) connected directly to V_{HI} (pin 6). The inverting input (pin 3) is brought out to the external positive sense terminal (for remote sensing) and also to S1a, which allows it to be connected directly to the positive output (pin 1) for local sensing.

Op amp A4 is connected in the same way, as the negative output voltage buffer. Here, the op amp's non-inverting input (pin 13) is connected directly to the reference cell's V_{LO} output (pin 8), while the inverting input (pin 14) is brought out to the negative sense terminal for remote sensing and also to S1b, to connect it directly to the negative output (pin 15) for local sensing.

So what is the purpose of the 'optional' trimpot VR1? It is for trimming the AD588's output voltage to higher

What this voltage reference cannot do

This 10V DC reference is very handy if you want to check the DC accuracy of your digital multimeter, but it cannot tell you anything about your DMM's accuracy in its other modes, such as DC and AC current, AC voltage and resistance. So, just because you have done a simple check on the DC voltage accuracy, don't let it lull you into a false sense of security that everything is well with your DMM.

In fact, it is possible that this 10V DC reference may alert you to the fact that your DMM has drifted well away from its initial calibration, which may have been pretty good when you purchased it. How many years ago was that?

If you are using DMMs in your occupation, they should be calibrated every year or so, otherwise you cannot really trust the readings. Moreover, if you have dropped your multimeter, it definitely should be suspected, particularly if its internal calibration is performed by tweaking potentiometers. Let's face it, most DMMs get dropped from time to time – that's just normal.

If you need a full performance verification of all functions and ranges for your work then that is best performed by an accredited calibration laboratory.

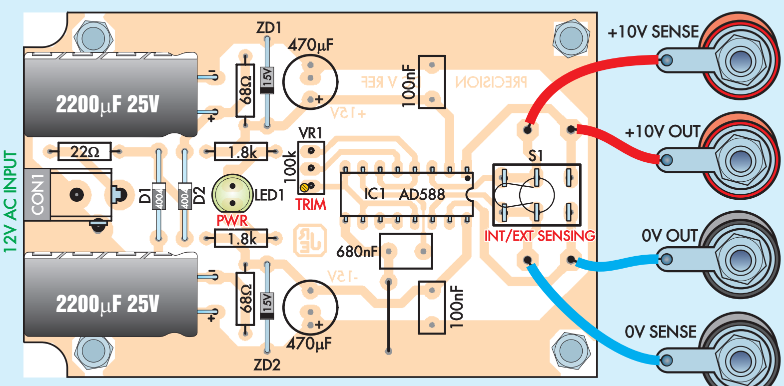
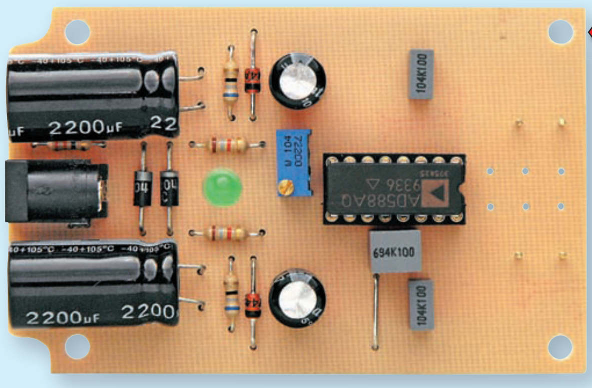


Fig.3: follow this diagram to install the parts on the PC board and complete the external wiring. Note that switch S1 actually mounts on the lid of the case and not directly on the PC board – see text.



This view shows the completed PC board with the optional trimpot (VR1) in position. Install VR1 only if you intend calibrating the unit against a high-precision 10V reference.

Parts List

1 diecast aluminium box, size 111mm × 60mm × 54mm (Jaycar HB-5063 or similar)
1 PC board, code 805, available from the *EPE PCB Service*, size 84mm × 53.5mm
1 DPDT on-on mini toggle switch (S1)
1 2.5mm PC-mount DC power socket (CON1)
1 16-pin machined IC socket
2 binding post terminals, red
2 binding post terminals, black
4 M3 × 25mm tapped metal spacers
4 M3 × 6mm screws, countersink head
4 M3 × 6mm screws, pan head
1 100kΩ 25T top adjust trimpot (optional – see text)
1 150mm length blue hookup wire
1 150mm length red hookup wire
1 100mm length 0.7mm tinned copper wire

Semiconductors
1 AD588AQ or AD588JQ voltage reference (IC1) – available from Farnell UK, part no. 411700 (see: **http://uk.farnell.com**)
2 15V 1W Zener diode (ZD1,ZD2)
1 5mm green LED (LED1)
2 1N4004 1A diodes (D1,D2)

Capacitors
2 2200µF 25V radial electrolytic
2 470µF 16V radial electrolytic
1 680nF MKT metallised polyester
2 100nF MKT metallised polyester

Resistors (0.25W 1%)
2 1.8kΩ 1 22Ω 2 68Ω

precision than its 'out of the box' ±3mV rating. We have made provision for the trimpot to be added to the PC board for this purpose, but there is no point in fitting the trimpot unless you have access to a very high precision 10V reference.

AD588 availability

That's about it regarding circuit operation. However, before we move on to discuss the project's construction, a quick word about versions of the AD588 chip and its availability.

Analog Devices apparently make five different versions of the AD588, one in a small outline (SOIC-W) SMD package and the others in 16-pin ceramic DIL packages. The four CERDIP devices have different initial error, temperature range and temperature coefficient values. They range from the AD588BQ with 1mV of initial error, a -25°C to +85°C range and 1.5ppm/°C tempco, down to the AD588JQ with 3mV of initial error, 0-70°C range and 3ppm/°C tempco. The AD588BQ is the most expensive (as you would expect), while the AD588JQ is the least expensive.

If you want to build the unit with the highest possible precision and performance, this can be done by using the BQ or KQ versions of the AD588. You may be able to 'special order' these from Farnell, but be warned: the BQ version is considerably more expensive than the AQ version we have specified, and the KQ version is probably much more expensive as well.

Construction

Apart from the output terminals, virtually all the components are mounted on a single PC board measuring 84mm × 53.5mm. The PC board is available from the *EPE PCB Service*, code 805. The board fits inside a diecast aluminium box (111mm × 60mm × 54mm), which provides both shielding and physical protection. The output and remote sensing terminals are all mounted on one end of the box, while the internal/external sensing switch (S1) is mounted directly on the lid, with short wire leads connecting it to the PC board – see photos.

The PC board itself is mounted on the back of the lid and is supported via four M3 × 25mm tapped metal spacers. Unlike switch S1, the power indicator LED (LED1) mounts directly on the board and protrudes through a hole in the lid.

The parts layout on the PC board and the external wiring are shown in Fig.3. Note that trimpot VR1 is optional, as mentioned earlier. Note also that IC1 should not be soldered directly into the board, but plugged into a *high-quality* 16-pin DIL socket.

Below: the PC board is 'hung' off the lid of the case on M3 × 25mm tapped metal spacers and secured using M3 × 6mm screws. Note the 'extension' leads attached to the switch terminals. Right: the view inside the case with the output terminals mounted and wired back to the board.

Begin the assembly by installing the single wire link on the board, then fit the five fixed resistors, followed by the three non-polarised MKT capacitors. The four electrolytic capacitors can go in next. Be sure to orient these as shown in the overlay diagram and note that the two 2200μF electrolytics are mounted on their side, with their leads bent at right-angles to go through their respective holes in the PC board.

Follow these parts with diodes D1 and D2 and Zener diodes ZD1 and ZD2. LED1 can also be installed. It mounts vertically with the bottom of its plastic body about 22mm above the board surface. Be sure to install all these parts with the correct orientation.

If you are going to use the optional trimpot VR1, fit it now. It must be installed with its top adjustment screw at lower left (this is to align it with the adjustment hole drilled in the lid).

The PC board assembly can now be completed by installing the DC power socket (CON1) and the socket for IC1. Orient the IC socket with its notched end towards the right, as shown in Fig.3. Leave IC1 out for the time being.

Preparing the case

Fig.4 shows the drilling details for the case. Note that the larger holes are best made by using a small pilot

Voltage standards: a brief history

From 1905 to 1972, the national standard of EMF or voltage used by the USA was the Weston Cell, a wet chemical primary cell or 'battery' developed in 1893 by Edward Weston, of Newark in New Jersey. Weston had improved on an earlier 'voltage standard' cell, which had been invented by English engineer Josiah Latimer Clark in 1873. Weston cells were adopted as the International Standard for EMF/voltage in 1911.

Weston's cell had a cadmium-mercury amalgam anode, a pure mercury cathode, a paste of mercurous sulphate as the depolariser and a saturated solution of cadmium sulphate as the electrolyte. It was built in an H-shaped glass container, with the anode at the bottom of one 'leg' and the cathode in the other leg. The electrical connections to the two electrodes were made by platinum wires fused through the glass at the bottom of the legs.

The Weston cell provided an accurate 1.0183V reference with a very low temperature coefficient – much lower than Clark's earlier cell. However, like the Clark cell, it could supply virtually no current and could only be used to provide a reference voltage for high-resistance measuring circuits like the classical 'potentiometer' (a kind of bridge which compared a known proportion of an unknown voltage against the reference voltage, so no current flowed when the two voltages were 'in balance').

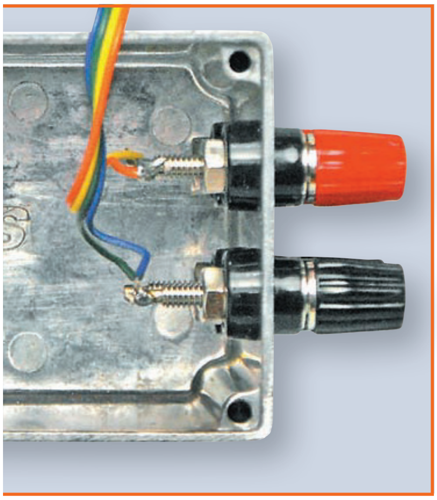
Weston cells were used as the US and International standards for EMF/voltage until 1972, when a new standard came into use: the Josephson Junction Voltage Standard (JJVS). This operates on a very different principle: the phenomenon of quantum-mechanical tunnelling currents which flow between two weakly coupled superconductors separated by a very thin insulating layer.

This is known as a Josephson junction, and the current is known as the Josephson current – named after British physicist Brian David Josephson, who had predicted the effect in 1962. An improved version of the JJVS was subsequently developed In the 1980s: the Josephson Array Voltage Standard or JAVS. By the way, because Josephson junctions and arrays depend on superconductivity for their operation, they must be operated in a liquid nitrogen environment at 77K (–196°C).

Essentially, a JAVS forms a frequency-to-voltage converter, whose conversion factor is exactly reproducible (the agreed figure is 0.4835979GHz/μV). Because frequency can be measured extremely accurately using caesium-beam and caesium fountain standards, the JAVS therefore provides a practical voltage standard of similar accuracy. In fact, the estimated accuracy of current JAVS 10.0V voltage standards is typically quoted as ±0.017ppm.

More information on the Weston Cell can be found in Weston's original US patent (No. 494,827), available on the US Patent Office website.

Further information on the Josephson effect, JJVS and JAVS standards can be found at: **http://en.wikipedia.org/wiki/Josephson_effect** and at: **http://www.nist.gov/eee1/**



drill to start with and then carefully reaming each hole out to its correct size.

Once you have drilled all the holes, mount the output terminals in place and tighten their mounting nuts firmly to prevent them from later coming loose. That done, solder a short length (say 75mm) of insulated hookup wire to the solder spigot at the rear of each terminal, ready to make the connections to the PC board.

Next, attach the front-panel label to the lid. This label can be made from a piece of plain or coloured thin card. The top diagram in Fig.4 can be used as a guide for marking out the required card hole positions. See the main title page for label lettering. It can then be covered with protective self-adhesive transparent film. Attach the label using a thin smear of silicone sealant, then cut out the holes using a sharp hobby knife.

Toggle switch S1 can now be mounted in position on the lid. Tighten its mounting nut firmly, then fit six 15mm lengths of tinned copper wire to its connection lugs (these leads later pass through their corresponding holes in the PC board). Loop the end of each wire through the hole in its switch lug before soldering, to make sure these joints can't come adrift when the outer ends of the wires are soldered to the board copper pads.

The next step is to attach an M3 × 25mm tapped metal spacer to each corner of the PC board. Secure these using four M3 × 6mm pan-head machine screws, then install the leads between the output terminals and their corresponding PC board pads – see Fig.3.

IC1 can now be plugged into its socket. Be sure to orient it correctly and make sure that all its pins go into the socket – ie, not down the outside of the socket or folded under the IC itself. The PC board can then be attached to the lid.

Note that the extension wires fitted to switch S1 must all pass through their matching holes in the PC board, while LED1 must pass through its corresponding hole (C) in the lid. Secure the board to the lid using four countersink-head M3 × 6mm screws, then solder the six switch leads to their board pads.

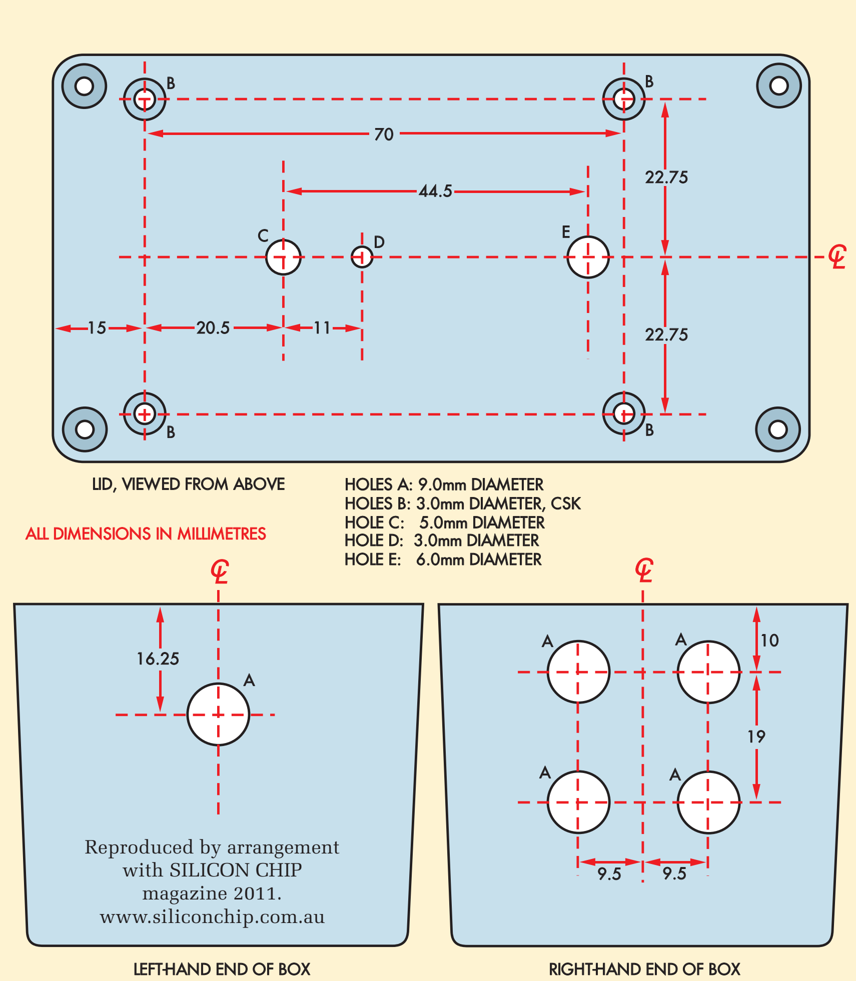


Fig.4: the drilling details for the case. Use a pilot drill to start the larger holes, then step up to the correct size using a larger drill and a tapered reamer.

The unit can now be completed by fastening the lid/PC board assembly to the box using the screws supplied.

Using it

There are no adjustments to be made to the Precision Voltage Reference if you don't have access to a very high precision voltage source to calibrate it. As stated previously, without calibration, it will operate with better than ±3mV precision, as provided by the AD588AQ chip itself.

In that case, it's merely a matter of switching S1 to the internal sensing position and applying power (12V AC) to CON1. LED1 should light immediately to show that the unit is operating and 10.000V ±3mV will

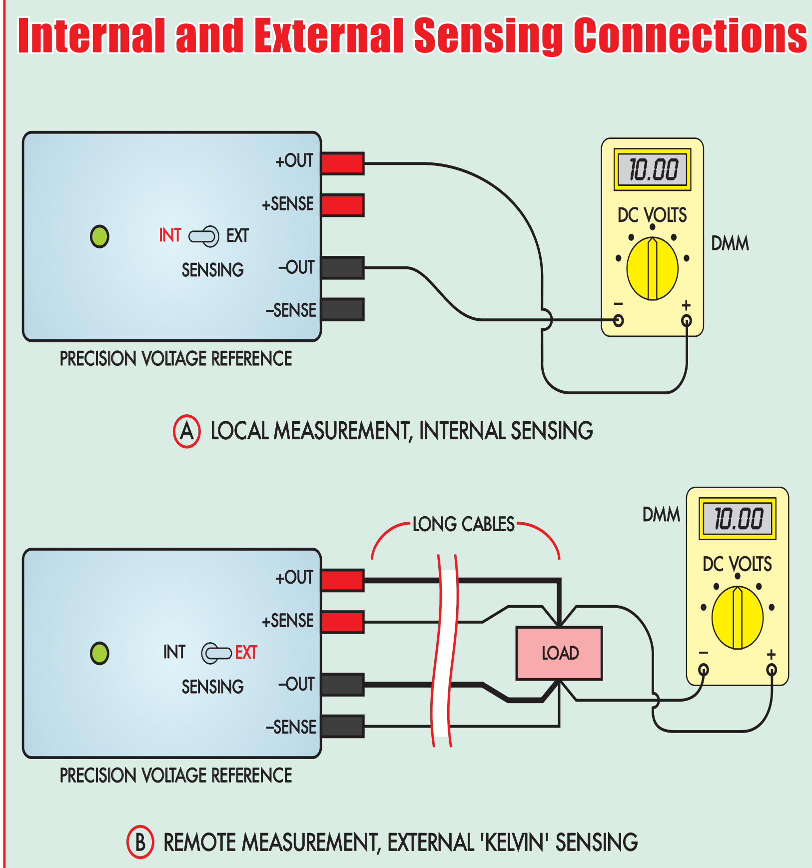


Fig.5: how to connect the Precision DC Voltage Reference for both local (A) and remote (B) measurements (the latter compensates for cable losses).

now be available at the upper output terminals, ready for checking your DMM or whatever.

This 'internal sensing' configuration is the one to use for most simple jobs like DMM calibration, with the DMM input leads connecting directly to the Precision Voltage Reference's upper output terminals.

Cable compensation

The only occasions when it's preferable to use external sensing or 'Kelvin connections' will be when you are supplying the unit's voltage to a load at the end of a cable and the load is drawing sufficient current to introduce a significant voltage drop due to the cable resistance.

In such situations, you'll need to extend the output sensing terminals of the Precision Voltage Reference to the load end of the cable via a second pair of leads, as shown in Fig.5. Then S1 is switched to the 'external sensing' position, so that the AD588 senses the output voltage right at the load end of the cable rather than at its own end. As a result, it will maintain the load voltage at the correct 10.000V, compensating for the cable drop.

All of the foregoing also applies if you build the unit with trimpot VR1 and/or use an AD588BQ/KQ for higher precision. The only complication in these latter situations is that you'll need to compare the output of the Precision DC Voltage Reference with a higher precision source and adjust VR1 to trim its output as close as possible to 10.0000V before you can put it to use.

EPE

The times they are A-changing!

TechnoTalk

Mark Nelson

Electronics has long been the catalyst of change, but has this revolution reached an uncontrollable fever pitch? Mark wonders after four separate end-of-an-era events were announced in a single week recently.

IS IT synchronicity, or simple coincidence that in the same week two cornerstones of electronics announced their significant transformation? Across the Atlantic, in what observers herald as a genuinely unprecedented move, the electronics component distributor Digi-Key Corporation has binned its printed catalogue and customer magazine. If its name is unfamiliar, let me explain that Digi-Key is the fifth largest electronics outlet in the USA, with annual sales of $1.5 billion.

Up to now, the company was mailing over a million heavyweight catalogues a year, and there's the rub. By moving all product information online, the company can eliminate its massive printing and postage costs, as well as saving several forests.

Unsurprisingly, the firm is extremely proud of its transition into a totally Internet-based distributor, using state-of-the-art technology to support customers and streamline sales. It also demonstrates environmental awareness and social responsibility. Where America goes, Britain follows; so how soon before Farnell, CPC, RS and Maplin follow suit?

In the same week, British industry magazine *Computer Weekly* (and its trade paper counterpart *MicroScope*) announced it was discontinuing the print versions of both titles to become online only. These are not the first magazines to abandon their print versions in favour of digital distribution, but it makes you wonder how much longer its former companion *Electronics Weekly* will continue as a print magazine.

More farewells

Reinforcing the feeling of synchronicity, it was announced during the same week that *Carphone Warehouse* was pulling out of selling laptops and netbooks, to concentrate on 'pad' and tablet computers. Few would deny that *Carphone Warehouse* is well ahead of the game; it was the first high-street retailer to sell laptops back in 2008. The firm set a tough challenge to traditional PC sellers such as *PC World*, *Dixons* and *Comet*, soon filching a 10 per cent share of their market.

For many users, a smartphone has all the IT functionality and power they need on the move. An added attraction is that a lightweight 'small box' product doesn't use a large carry case that screams 'steal me' to thieves. Industry analysts predict tablet sales will increase to 55 million this year and 150 million by 2015. This is against a background of declining sales for full-size PCs that are forecast to fall this year from 417 to 387 million.

In the same week (honestly!) came the fourth farewell, when *Electrical & Radio Trading* proclaimed CDs' days are numbered. Philip Hansen of the *British Audio-Visual Dealers Association* declared that the future of music retailing is by download, not on 'silver' discs made of plastic (high-street music shops are struggling and HMV is the last national bricks and mortar chain selling CDs). If you need evidence for his contention, just look at the burgeoning sales of iTunes (over 10 billion songs sold) and the Ethernet port increasingly found on new hi-fi equipment.

Pros and cons

You can't stop progress, so you might as well go with the flow, even if it's unclear whether digital downloads are entirely progressive. The benefits are undoubted: at any time of the day you can give in to the urge to own a particular piece of music. A minute later it's yours – yippee! – and if you're a savvy surfer you may even manage to snaffle it without paying. And for every service like Spotify, there will be a Spotify recorder, such as Dojotech Software's product (**www.dojotech.com/Software/SpotifyRecorder.aspx**).

On the other hand, you may feel uncomfortable with 'l-ssy c-mpr-s-ion' techniques and would prefer the full-fat sound that you get on a CD (even if this contains digital 'sound gaps' that are thankfully absent on vinyl analogue recordings). Digital downloads don't give you the tactile pleasure of clicking open the clear jewel case or the informative booklet and sleeve notes.

That said, some enterprising people have warehoused vast collections of CD and DVD sleeve wrappers that you can download if you have, ahem, mislaid your originals (**www.cdcovers.cc/**, **www.allcdcovers.com/** and **www.dvdcoversfuzion.com**).

There's no denying the logic of ditching shelves of CDs and DVDs and instead 'centralising' them on a single hard disc that's barely larger than a VHS case. But this option also has its perils. Remember the widespread wailing and gnashing of teeth in July 1999 when Amazon demonstrated the power of digital rights management (DRM) by remotely deleting paid-for books, including *Animal Farm*, *1984* and some Harry Potter novels from customers' Kindle devices without warning?

A Google search for phrases such as 'delete DRM' or 'strip DRM' will turn up many tutorials on this subject, but most download customers will remain unaware of the need to back up their purchases offline, where they cannot be snatched back by the vendor. Hard drives are not perfect either, and catastrophic failure cannot be ruled out. Frequent backing up is the best security against losing all your hard-won entertainment. Better still, don't get rid of your CDs and DVDs!

Fighting back

If you find the unstoppable pace of technical revolution too much, why not turn its forces on itself? If you'd like to restore peace and quite around you, how about a cellphone jammer? Unfortunately, they are illegal to use in the UK, but there's no harm in taking a look at: **www.globalgadgetuk.com/cell-phone-jammers.htm** to see what they offer. And then visit **http://electronics.howstuffworks.com/cell-phone-jammer.htm** to see how they work.

Equally ingenious and inspired is TV-B-Gone. This gadget, no larger than a key fob, is a TV remote control with a difference. All it does is turn tellies off, and that's any and every telly.

It works by sending out a stream of infrared signals that contain the codes to switch off every brand of television. Just point the device at a telly that annoys you (in a pub perhaps) up to 50 feet away, hold down the button for at least one second and TV-B-Gone will do its business. It takes 69 seconds to send every code, but the most popular ones are sent first.

Extremely childish of course, which is why I do not recommend you visit the website at: **www.tvbgone.com** or then go to Amazon UK to buy it cheaper. Certainly, do not read about the TV Polterguist (correct spelling – find it on eBay UK), which is a small gadget that works on similar lines. Leave in a room and it then turns the TV on and off at random intervals, between five and 20 minutes, 24hrs a day for weeks on end.

Part 2 By JIM ROWE

GPS Driver For The 6-Digit GPS Clock

Based on the GlobalSat EM-408 GPS module, this compact GPS receiver/driver board mates with the 6-digit display described in Part 1 to form a self-contained GPS clock. It can also be housed separately and used to provide NMEA 0183 time and date information to a PC, via a serial port.

THE *6-Digit GPS Clock Display* described in last month's issue was originally conceived as an attachment for the author's *GPS-Based Frequency Reference* (See *EPE*, April-May 2009). The idea was that since the NMEA 0183 stream of GPS time, date and navigational data was available from the GPS receiver in the Frequency Reference, we'd provide a 'smart' display unit to receive this data stream, extract the time information and display it in either its native UTC form or converted to local time.

However, before the design was published, we realised that it would also be of interest to many more people than those who had built the GPS-Based Frequency Reference. That's because it could be turned into a fully self-contained GPS Clock simply by building a GPS receiver and display driver module into the same enclosure. And by taking advantage of one of the low-cost GPS receiver modules currently available, this could be done surprisingly cheaply – with the complete clock costing less than £120. Not bad for a clock offering you very close to 'atomic time' (and updated every second), wouldn't you say?

Clock driver

So that's the story behind the little GPS Clock Driver board described here. Its main application is to convert last month's 6-Digit Display into a self-contained GPS clock. Alternatively, it can be used to feed the GPS/NMEA 0183 data stream into a PC via a standard serial port. You can then use a freeware software program such as 'GPS Clock' to process and display the data – see panel.

How it works

As mentioned earlier, the heart of the new driver board is the GlobalSat EM-408 'GPS Engine' module. This module was also used in Geoff Graham's *GPS-Synchronised Analogue Clock*, described in the March 2011 issue.

The EM-408 is quite small, measuring just 36.4 × 35.4 × 8.3mm. Despite this, it includes a built-in microwave 'patch' antenna and is very sensitive (–159dBm). This allows it to operate reliably indoors using just the patch antenna, without requiring an external antenna or cabling. The current drain is

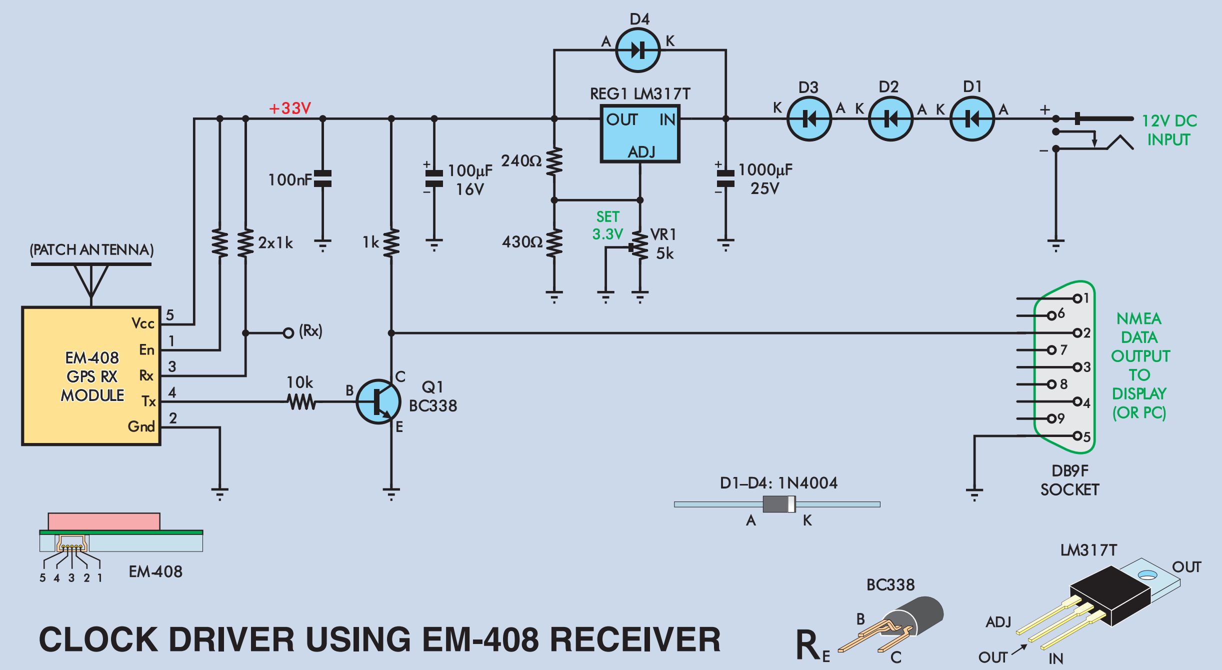


Fig.1: the circuit uses an EM-408 GPS receiver module and an adjustable LM317T regulator to provide a 3.3V supply. The output from the GPS module appears at pin 4 and is inverted by transistor Q1 to drive the display board.

also surprisingly modest, at just 44mA continuous from a 3.3V supply rail.

As a result, all we have to do to use it as a clock driver is to provide it with a source of 3.3V DC power, plus a simple buffer stage to interface its NMEA 0183 data stream output to the serial data input of the clock display (or a PC). Fig.1 shows the circuit details.

In operation, the driver board operates from the same +12V DC supply used for the display board via its own 3.3V regulator circuit (REG1). REG1 is an LM317T adjustable regulator, and is configured in standard fashion, with trimpot VR1 used to set the output voltage to 3.3V, as required by the EM-408.

Diodes D1 to D3 provide both supply polarity protection and an additional 1.8V voltage drop from the 12V source to reduce the power dissipation of REG1. Diode D4 protects REG1 from reverse current damage.

As shown in Fig.1, the EM-408's Vcc input (pin 5) is connected to the +3.3V line, while the En input (pin 1) is pulled high via a 1kΩ resistor to the same line, to enable it. Also pulled up via a 1kΩ resistor is the Rx input (pin 3), which is provided on the EM-408 to allow it to be fed with NMEA setting-up commands in some applications.

Parts List – GPS Clock Driver

1 PC board, code 806, available from the *EPE PCB Service*, size 122mm × 57mm
1 GlobalSat Technology EM-408 GPS Engine module with cable (Altronics K-1131)
1 short length of double-sided adhesive foam tape
1 PC-mount 2.5mm DC connector (optional – see text)
1 PC-mount DB9F connector (optional – see text)
1 M3 × 6mm long M3 pan-head screw
4 M3 × 30mm screws, countersink head
9 M3 nuts
1 5kΩ horizontal trimpot (VR1)

Semiconductors
1 LM317T adjustable regulator (REG1)
1 BC338 NPN transistor (Q1)
4 1N4004 diodes (D1-D4)

Capacitors
1 1000µF 16V radial electrolytic
1 100µF 16V radial electrolytic
1 100nF monolithic ceramic

Resistors (0.25W 1%)

1 10kΩ	1 430Ω
3 1kΩ	1 240Ω

Where To Get The EM-408
The EM-408 GPS Engine module is available from SparkFun Electronics of Boulder, Colorado, USA. Their website is at **www.sparkfun.com** and payment can be made using most popular credit cards. At the time of writing, they were offering the EM-408 GPS module for about £40 plus £2 for handling and shipping (do check current prices) .
Another source for the EM-408 is Altronics for about £65 (Cat. K-1131). (**www.altronics.com.au**)

We don't need to do this in the present project, because it comes set up to do what we want by default – ie, it supplies the NMEA data stream at 4800bps and also supplies the $GPRMC sentence we need to extract the time.

The NMEA data stream emerges from the EM-408 at its Tx output (pin

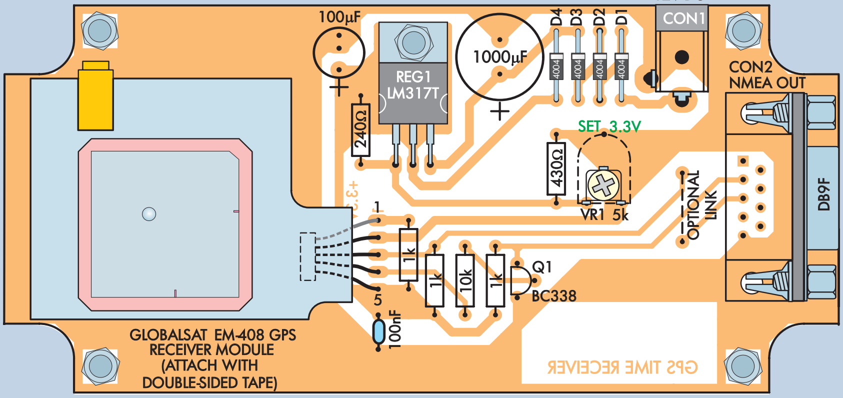
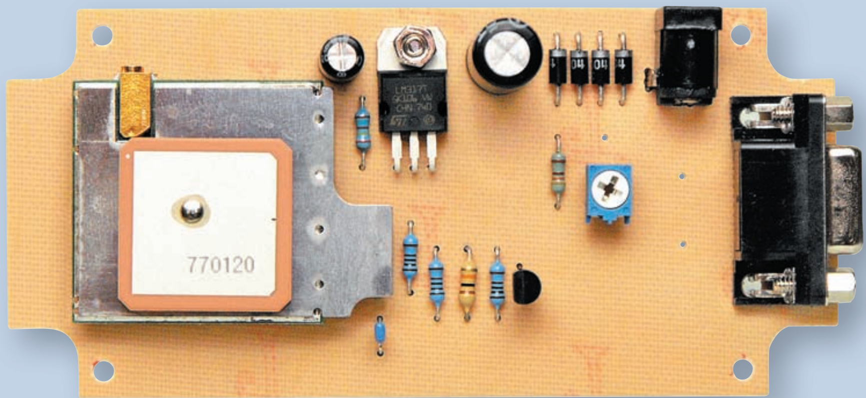
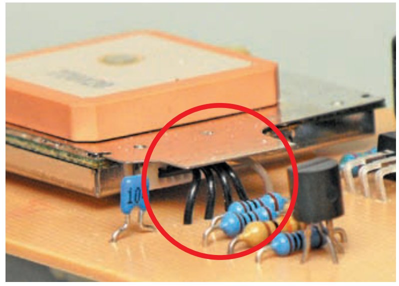


Fig.2: install the parts on the PC board as shown here. Note that CON1 (the DC socket) and CON2 (the DBF9 connector) are both left out if you intend installing this board in the same case as the display board (see Fig.3).



This view shows the completed assembly. The GlobalSat EM-408 GPS module is attached using double-sided adhesive foam tape.



This close-up view shows how the EM-408 is connected to the PC board via the 5-way interface cable supplied with the module – see text.

4) and is then fed to a simple inverting buffer stage based on transistor Q1. The inverted signal appearing at Q1's collector (C) is then fed to the serial input of the display board (or to the serial port of a PC), either directly or via a DB9F socket and serial cable.

Board assembly

The assembly is straightforward, with all parts, including the EM-408 GPS module, installed on a small PC board measuring 122mm × 57mm. This board is available from the *EPE PCB Service*, code 806. The board has cut-outs in each corner so that it can be housed in a standard UB3-size (130mm × 68mm × 44mm) utility box, if you want to build it as a separate unit.

Fig.2 shows the component layout and assembly details. Note that there's provision to mount both a 2.5mm DC input socket (CON1) and a DB9F socket (CON2) on the board. However, these are fitted only if you intend building an external unit. Leave these parts out if the module is to be mounted in the clock case (it's wired directly to the display board).

The optional link shown just to the right of trimpot VR1 can also be left out, as it's not needed for this particular project.

Begin construction by installing the resistors, followed by trimpot VR1 and the 100nF monolithic capacitor. Table 1 shows the resistor colour codes, but it's also a good idea to check each one using a multimeter before installing it. Note the 10kΩ resistor that's second to the left from transistor Q1 – be sure to install it in its correct location.

The two electrolytic capacitors can now go in, taking care to fit them with the correct orientation. Follow these with the four diodes (D1-D4), then install transistor Q1 and regulator REG1. As shown, the latter is installed with its leads bent down at right angles about 6mm from its body, so that they go through their matching holes in the board.

Secure REG1's metal tab to the board using an M3 x 6mm screw and nut before soldering its leads. Don't solder its leads first. If you do, the solder joints could be stressed as its tab is bolted down and this could lift (or crack) the copper tracks.

Check that the diodes, transistor Q1 and the regulator are all installed with the correct orientation.

Fitting the EM-408

The EM-408 GPS engine module is next on the list. This is attached to

Table 1: Resistor Colour Codes

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	1	10kΩ	brown black orange brown	brown black black red brown
❑	3	1kΩ	brown black red brown	brown black black brown brown
❑	1	430Ω	yellow orange brown brown	yellow orange black black brown
❑	1	240Ω	red yellow brown brown	red yellow black black brown

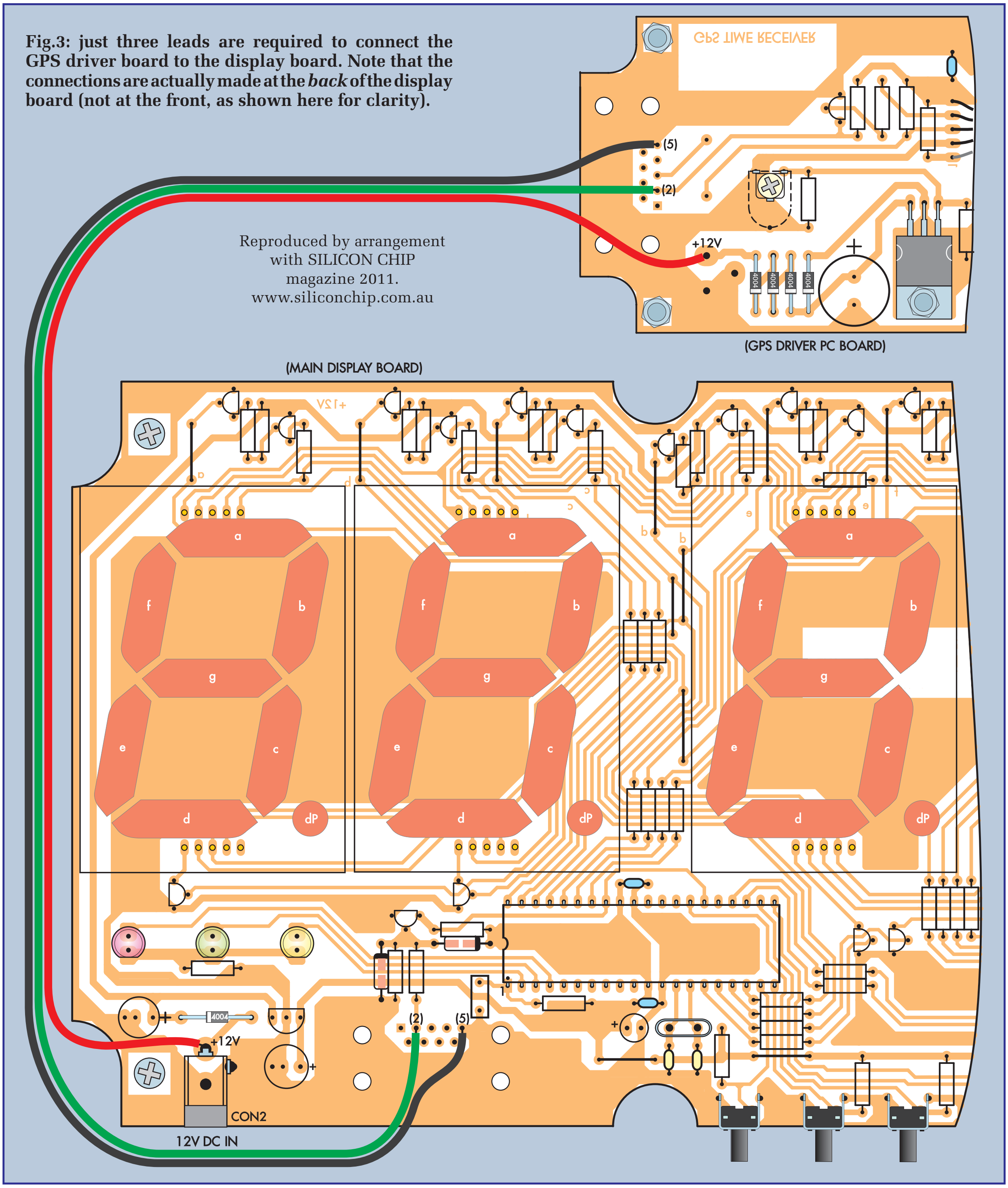


Fig.3: just three leads are required to connect the GPS driver board to the display board. Note that the connections are actually made at the *back* of the display board (not at the front, as shown here for clarity).

the top of the PC board using a strip of double-sided adhesive foam tape and must be oriented as shown in Fig.2. However, before fitting it in place, you have to make the interconnections between it and the PC board.

As supplied, the EM-408 comes with a matching 5-way interface cable. This is about 25mm long and is fitted at each end with a mini 5-way SIL plug, one of which is plugged into a matching socket on the GPS module itself.

For this application, you have to cut the cable in half and then use one half to make the connections between the module and the PC board. Remove about 4mm of insulation from the five leads and solder-tin them before

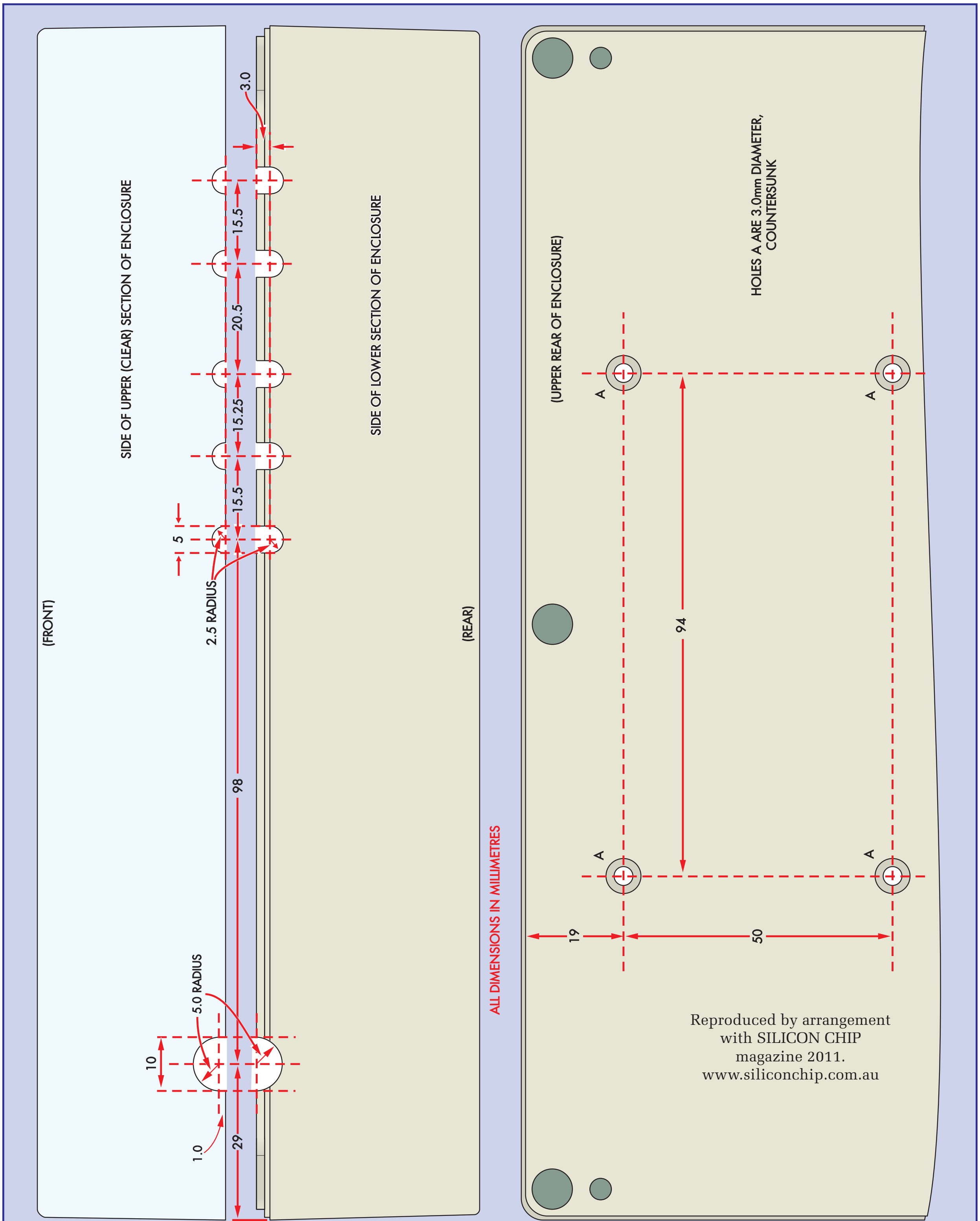


Fig.4: follow this drilling diagram to mount both the GPS driver module and the display board in the same case. The semi-circular notches along one edge of the lid and along the top of the base can be made using rat-tail files of the correct diameter. (Note: if you intend mounting just the display board in the case, use the drilling diagram published in Part 1 last month).

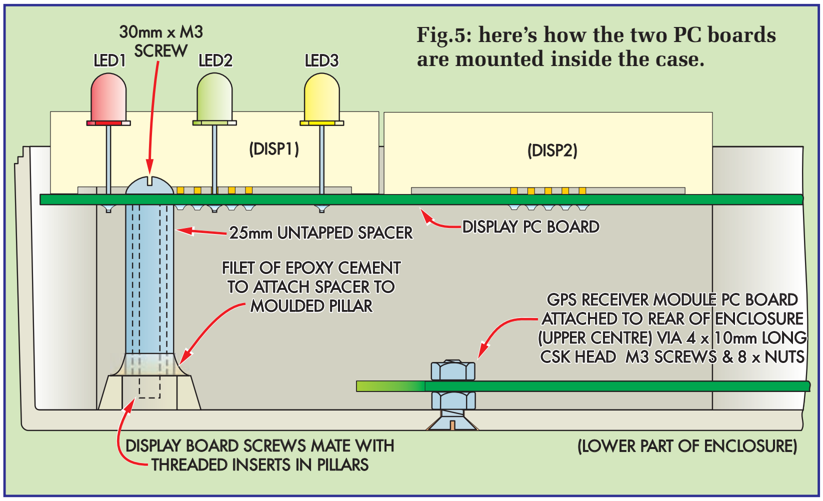


Fig.5: here's how the two PC boards are mounted inside the case.

soldering them to the PC board. Be sure to feed the leads through the board holes in the correct sequence and note that the wire with the grey insulation goes into the uppermost hole (marked '1' on Fig.2).

After they have all been soldered, plug the end of the cable into the matching socket on the end of the EM-408 module. This is done with the module oriented socket-end-down and roughly vertical with respect to the board. Take care to ensure that the plug and socket mate correctly – they're very small and are polarised.

Once the connection is made, fit the strip of double-sided adhesive foam to the underside of the EM-408. That done, remove the protective tape from the outer surface of the adhesive foam and carefully swing the module down so that it rests on the top of the PC board. During this process, be sure to leave a small amount of slack in the cable so that the plug isn't pulled out of its socket.

Once the module is in the correct position (see photo), press it down gently to ensure that the adhesive foam 'grabs'.

Finally, if you intend installing the board into a separate case, fit the DC socket (CON1) and the DBF9 socket (CON2). Conversely, leave these parts out if the module is going to be installed in the same case as the display board.

That's it – assembly of the module is now complete.

Setting up

Setting up simply involves adjusting trimpot VR1 to set the output of regulator REG1 to 3.3V to give the correct supply voltage for the EM-408 GPS module.

To do this, first set VR1 to mid-range, then apply power from an external 12V DC source. If you're not using the DC socket, simply connect the supply's positive to D1's anode. The negative lead goes to the outside copper earth pattern.

Next, use your DMM (set to a suitable DC voltage range) to monitor the output from REG1 (eg, at its metal tab or at the lower end of any of the 1kΩ resistors). With VR1 set to mid-range, this should be close to 3.3V, but may be either slightly lower or higher than this figure. Adjust VR1 to set the voltage from REG1 as close as possible to the correct 3.3V.

The driver board assembly is now finished and can be fitted into either the clock display enclosure or a separate UB3-size box.

Drilling the case

We'll assume here that you want to fit the GPS driver module into the same case as the display board. If so, the first step is to connect a 200mm length of 3-way ribbon cable to the module's external wiring points – see Fig.3. The other end of this cable goes to the main display board, but leave this end disconnected for the time being.

Having attached the cable, the driver module and its associated display board can be installed in the case. Fig.4 gives the case drilling details. As shown, four holes must be drilled in the base (towards the top) and these are used to mount the driver module. They should all be countersunk (ie, on the outside of the case) using an over-size drill.

In addition, you have to cut notches along the mating edges of the top and

Using A PC To Display GPS Time

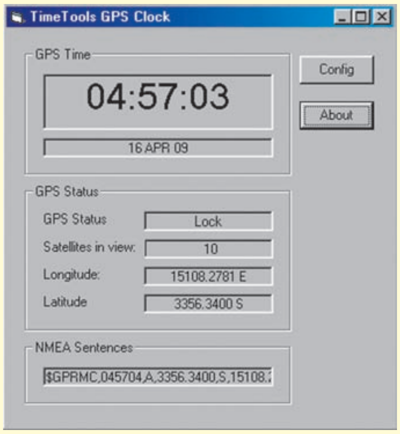


Fig.6: 'GPS Clock' from TimeTools shows UTC time plus longitude and latitude.

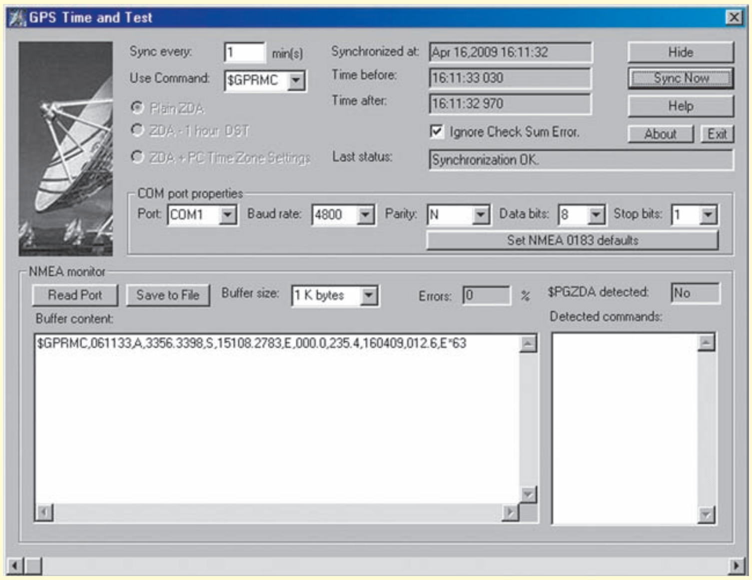


Fig.7: 'GPS Time And Test' synchronises your PC's clock to the GPS signal at preset intervals down to as low as one minute. Both programs also show the incoming NMEA data sentences.

IF YOUR PC has a serial port, then you can feed the NMEA 0183 data stream from this GPS driver module directly into it, and install software from the Internet to display GPS time.

Two useful programs are GPS Clock from Time Tools (freeware) and GPS Time And Test from BrigSoft (shareware, but free to try for 30 days). Download them from: www.timetools.co.uk/atomic-clock/fw/gps-clock.htm and from: www.abstime.com

Each does a slightly different job. For example, GPS Clock (Fig.6) shows the UTC time, along with the date, your longitude and latitude and the NMEA sentences.

By contrast, GPS Time And Test (see Fig.7) synchronises your PC's existing clock to the correct local time (ie, the clock is locked to the GPS time signal, but displays local time). Other information displayed includes the time before and after synchronisation, plus the NMEA sentence containing both the time and the coordinates for latitude and longitude. You can also set the synchronisation interval and set various COM port properties.

There's a lot more GPS software (both freeware and shareware) out there on the Internet. Check it out for yourself.

bottom halves of the enclosure (these provide access to the DC socket and the switches on the display board). These notches are best made using rat-tail files of the correct diameter, although it may be also possible to drill them if the two halves of the case are secured together.

Note that all these holes are in quite different positions from those shown in Fig.4 last month (ie, for the 'display only' enclosure). Note also that you don't need to make a cutout to provide access to the DB9F socket in this version, since the driver board cable is wired directly to the back of the main board.

Final assembly

Fig.5 shows the final assembly details. The new GPS driver board assembly is attached to the base of the enclosure using four M3 x 10mm countersunk-head machine screws, with four M3 nuts used as short spacers and another four nuts used to hold the board in place.

To allow plenty of 'breathing space' between the driver board and the main display board (especially to provide some clear space above the EM-408's patch antenna), the main board is mounted much further forward than in the 'display only' version. This is achieved by mounting it on 25mm-long untapped spacers. These sit on the existing moulded mounting pillars in the case, and the assembly is secured using M3 x 30mm machine screws.

Unfortunately, it's quite tricky to fit the main board into the enclosure with the 25mm spacers simply sitting on the moulded pillars. However, there is an easy way around this, and that is to glue the spacers to the tops of the pillars using 5-minute epoxy cement – see Fig.5.

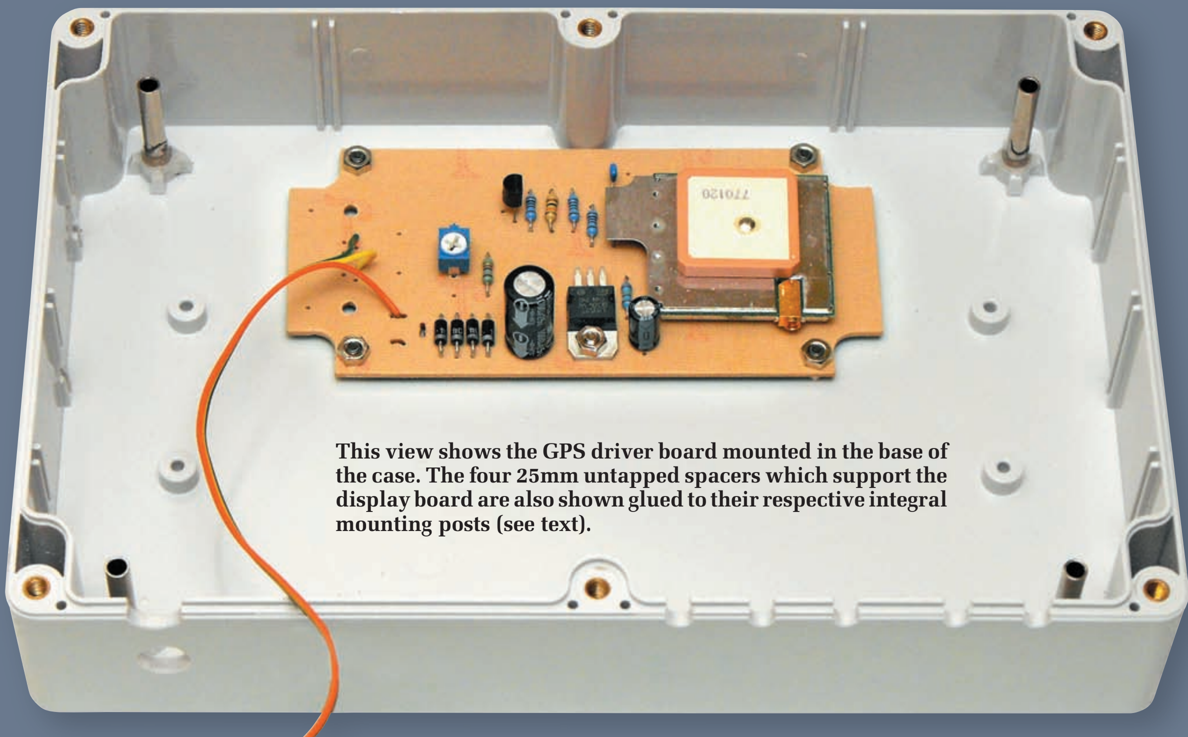
This is done by first 'clamping' each spacer to its pillar using a 30mm screw and flat washer. That done, you can apply a small 'fillet' of epoxy around the bottom of each spacer to hold it in position. Leave the assembly for a few hours to allow the epoxy to set reasonably well before removing the screws and flat washers.

Once the cement attaching the spacers has set, the three leads from the GPS driver board can be connected to the main display board. Note that these leads should be soldered to the rear of the main board, rather than to the front of the board as shown (for the sake of clarity) in Fig.3. If you prefer, you can fit PC stakes to the three wiring points (from the copper side) to accept the lead terminations.

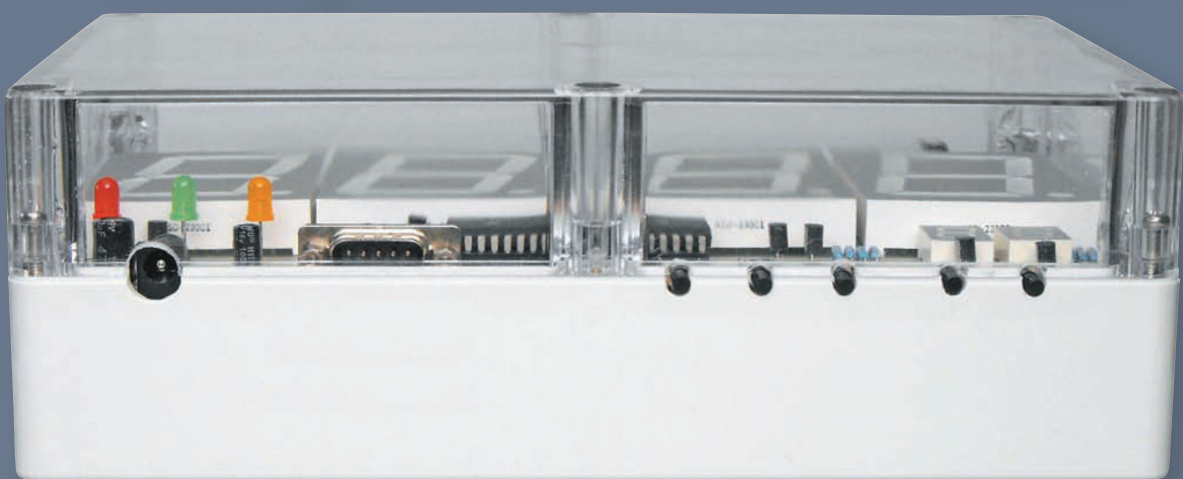
The assembly can now be completed by securing the display board in position using the M3 x 30mm screws and then fitting the clear lid to the case.

Applying power

You will need a 12V DC 300mA plugpack to power the unit. When this is



This view shows the GPS driver board mounted in the base of the case. The four 25mm untapped spacers which support the display board are also shown glued to their respective integral mounting posts (see text).



The DC power socket and pushbutton switches on the display board are accessed via holes in the side of the case (note: the DB9M connector is not necessary on the main board if mounting the GPS driver board internally).

connected, the displays should light up immediately and initially show '0000'.

After a short time (anywhere up to about 40s), the EM-408 GPS engine should begin sending the NMEA 0183 data sentences to the clock display. The unit will then display either UTC time, local standard time for eastern Australia or daylight saving time for eastern Australia, as selected by switches S1-S3.

If you live in a different time zone, then it's a simple matter to program in a different offset from UTC (the default offset is +10 hours for eastern Australia). This is done by pressing buttons S4 (hours increment) and S5 (minutes increment), as described last month in Part 1. The clock will then show the correct local time for your location.

Note that any changes you make to the offset from UTC time are stored in the micro's on-board memory and are retained even if the power is interrupted.

Note also that if the power is interrupted, the clock will automatically start displaying the correct time within 30 to 40s when power is subsequently re-applied. It all depends how quickly the EM-408 GPS module begins receiving data from a GPS satellite. ***EPE***

How to add a wireless infrared port to the DSP Musicolour – or in fact virtually any microcontroller project.

Musicolour IrDA Accessory

By
Mauro Grassi

Most PCs and laptops now offer an IrDA interface to enable communication without any physical connection. Now you can have the same facility for the DSP Musicolour – or for virtually any other microcontroller project.

IN the May, June, July and August 2010 issues of *EPE* we described the *DSP Musicolour*, an advanced light show based on the dsPIC30F4011 microcontroller from Microchip.

We mentioned that the firmware supports a high speed UART (universal asynchronous receiver transmitter).

The PC board below (which can replace the August infrared remote control PC board) adds an IrDA (Infrared Data Association) compatible serial port for the DSP Musicolour. This gives you all the features the original remote control offered, but adds a huge amount of additional features via the serial port of your PC.

Although the firmware in the DSP Musicolour supports a high speed UART running at up to 1.84Mbps, this interface will run at the much slower baud rate of 9.6Kbps, which is the default baud rate of the DSP Musicolour.

There is little need for it to be higher, since 9.6Kbps should be fast enough for most applications (if you wish to use a higher baud rate, you could connect a wired serial port).

IrDA is ideal for adding a serial port to a mains-rated circuit because the UART is completely isolated. Since it is infrared, it is also very convenient. Operating distance is not great – the specification says around 1m (without any obstacles) – but we found it works over greater distances than that.

Although this circuit was designed specifically for the DSP Musicolour, it could be adapted so as to add an IrDA-compatible serial port to any microcontroller project. We give you a recommended circuit to do this.

Because it was designed specifically for the DSP Musicolour, it also includes an infrared remote control receiver, thus effectively superseding the small infrared remote control PC board published in the August 2010 issue of *EPE*.

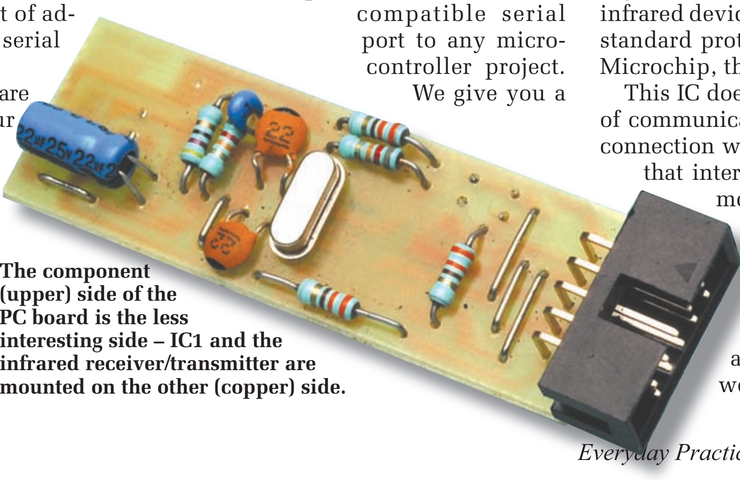
However, that project is still perfectly valid if you just want to control the DSP Musicolour using a remote control.

Protocol controller

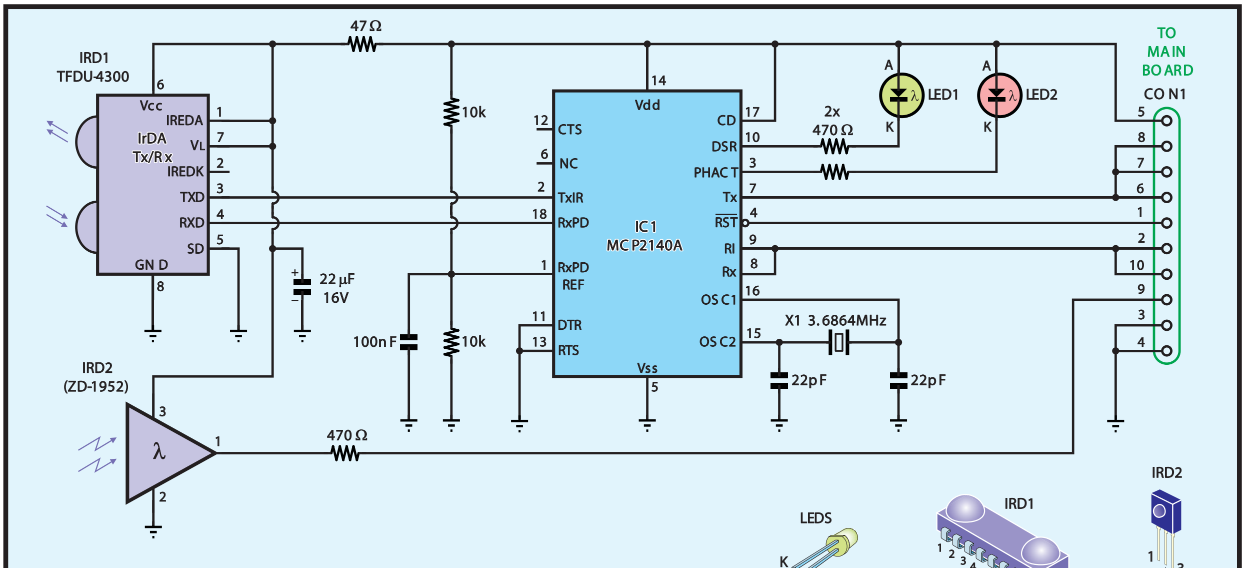
Essentially, the circuit (shown in Fig.1) is little more than a couple of infrared devices and a dedicated IrDA standard protocol controller IC from Microchip, the MCP2140A (IC1).

This IC does most of the hard work of communicating and setting up the connection with your PC. We suspect that internally, this IC is nothing more than a PIC microcontroller with a custom program.

In fact, Microchip provide the IrDA protocol stack source code as a free download on their website.



The component (upper) side of the PC board is the less interesting side – IC1 and the infrared receiver/transmitter are mounted on the other (copper) side.



MUSICOLOUR IRDA BOARD

Fig.1: the circuit is very simple, consisting of little more than a couple of infrared devices (IRD1 and IRD2) plus a dedicated IrDA standard protocol controller (IC1). CON1 connects to CON3 on the back edge of the DSP Musicolour PC board.

Don't use the MCP2140!

Note that the MCP2140 was the original IC in this series, but the MCP2140**A** is operationally different. The MCP2140A will not work as a replacement for the MCP2140 and *vice versa*. That's because the MCP2140A works with a 3.6864MHz crystal, whereas the MCP2140 works with a 7.3728MHz crystal. The two ICs also require different input signals into pin 18.

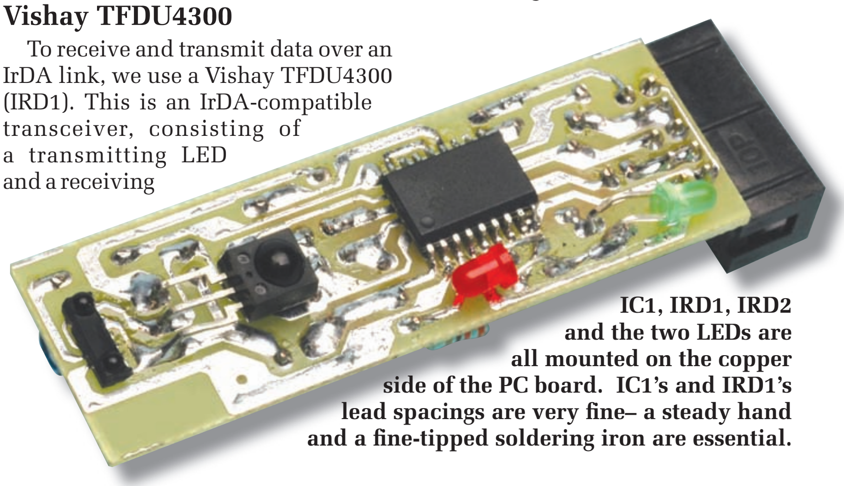
Speaking of the 3.6864MHz crystal, it connects to the two internal oscillator pins of IC1 (OSC1 and OSC2) to provide the system clock. A pair of 22pF ceramic capacitors provide the correct loading for the crystal.

Infrared transceiver IRD1: the Vishay TFDU4300

To receive and transmit data over an IrDA link, we use a Vishay TFDU4300 (IRD1). This is an IrDA-compatible transceiver, consisting of a transmitting LED and a receiving phototransistor. There is also a small amount of logic on the transceiver, as well as an amplifier. Such transceivers are commonly found on laptop motherboards and PDAs.

The operation of IRD1 is simple enough. Pin 1 (IREDA) is the anode of the internal infrared LED, while pin 2 (IREDK) is the cathode. In normal operation, you connect IREDA to the supply rail (in this case around +5V) and leave IREDK disconnected. IREDK can be used externally to turn on the LED, but in our case, the LED is switched on and off by internal logic.

Note that a current-limiting resistor is not needed with IREDA because the internal circuit of IRD1 limits the current through the LED.



IC1, IRD1, IRD2 and the two LEDs are all mounted on the copper side of the PC board. IC1's and IRD1's lead spacings are very fine– a steady hand and a fine-tipped soldering iron are essential.

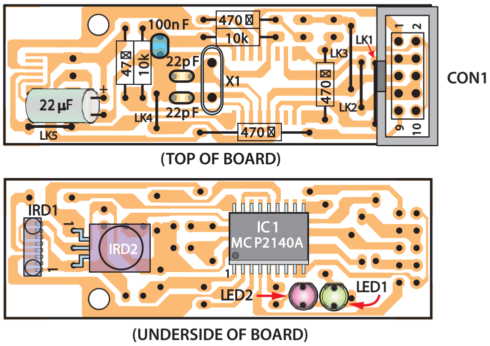
Pins 3 and 4 of IRD1 are the transmit and receive lines respectively, encoded as RZI (Return to Zero Inverted) signals. The MCP2140A (IC1) translates the NRZ (Non Return to Zero) encoding at its Tx and Rx pins to RZI signals at its TxIR and RxPD pins.

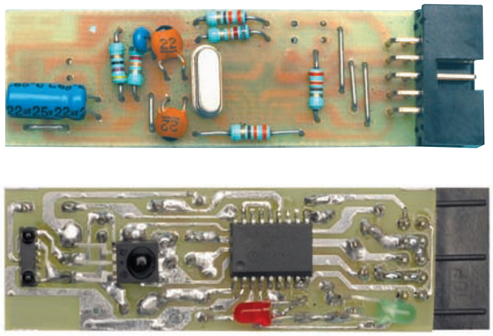
The IrDA is only half-duplex because the standard does not specify any optical isolation between the transmitter and receiver. When IRD1 is transmitting through its internal infrared LED, the receiver will also turn on, because the phototransistor is biased into conduction by the infrared light from the transmitting LED. The MCP2140A drives the transceiver in half-duplex mode, while presenting a full duplex interface to the host device (in this case, the dsPIC30F4011).

Pin 5 is the shutdown pin (SD), which is active high. When high, IRD1 goes into power conservation mode, drawing a very small current (typically down to 0.1μA at room temperature).

This is useful for battery-powered applications, but in our case, where we are supplying power from the Musicolour supply, we ignore this connection and tie it permanently to ground (0V).

Pin 6 is the supply voltage to IRD1 and pin 7 (V_L) selects the voltage level for the logic. This makes IRD1 customisable to different logic families with different threshold voltages. In our case, we connect it to the +5V supply





Figs.2a and 2b (left) show both sides of the PC board, with matching photos at right. Note that the 22µF capacitor needs to be installed flat, otherwise there would not be room for the PC board inside the DSP Musicolour case. These diagrams/pics are reproduced 1:1.

rail. Finally, pin 8 is the ground connection for IRD1.

The 22μF electrolytic capacitor is used to bypass the supply rail to IRD1 through the 47Ω resistor. The capacitor and resistor isolate the transceiver from a possibly noisy supply rail, which can interfere with IRD1's sensitive internal receiving circuit.

The two 10kΩ resistors form a voltage divider and are used to split the supply voltage and set the threshold for the receiving logic level for IC1.

Any level above the voltage at pin 1 of IC1 (RxPD Ref) is interpreted as a high level. Conversely, any level below that is interpreted as a low level. This pin therefore sits at around 2.5V. A 100nF capacitor is used to bypass this rail.

Physical activity

The DSR (Data Set Ready) output of IC1 will go low (thus turning on LED1 (green)) when a valid connection has been established with the host. It is locally emulated by IC1 and can indicate to a microcontroller that IC1 is ready to receive and transmit data. Thus, LED1 indicates that the MCP2140A has established a valid connection with your PC.

The PHACT (physical activity) output of IC1 (pin 3) is open collector and will sink current (thus turning on LED2 (red)) when there is a period of inactivity from the receiver for around 10 seconds. This pin can be pulled up to the supply rail using a resistor (1kΩ will do) and can then control pin 5 (SD) of IRD1 through an inverter, if you wish.

In this configuration, it puts the transceiver in low-power mode after a 10-second timeout. In our case, we use the output to control LED2 and to indicate to the user that no signal has been detected for at least 10 seconds. This can be useful for troubleshooting.

Pin 7 (Tx) and pin 8 (Rx) are the UART transmit and receive lines, while RI (Ring Indicator), CD (Carrier Detect), DTR (Data Terminal Ready), RTS (Request to Send) are all part of the serial port handshaking signals. Normally, IC1 will transmit and receive the state of these lines to the PC, emulating a full serial port.

In our case, we are really only using the raw 3-wire serial port, so we ignore these handshaking lines. We tie the DTR line to ground (0V), ignore the CTS output of IC1 and connect RI to Rx. This is done simply to make the layout of the PC board more compact. In any case, we only care about the Tx and Rx lines and these connect to the corresponding lines on the dsPIC30F4011 through CON1.

However, the RTS input of IC1 (pin13) is used locally to indicate that the MCP2140A is ready to receive data. We therefore tie this line permanently to ground (0V).

Finally, pin 4 ($\overline{\text{RST}}$) is an active low reset pin and is tied directly to pin 1 of CON1 (which connects to CON3 of the DSP Musicolour main board and is the reset line of the dsPIC30F4011 microcontroller).

The other infrared module (IRD2) is used for the RC5 remote control decoding, and is really a separate circuit on the same PC board.

Pin 3 and pin 2 provide the supply for IRD2, and pin 1 is the decoded remote control data, very similar to the remote control add-on board we described in the August 2010 issue of *EPE*.

A 470Ω resistor is used between the output of IRD2 and pin 9 of CON1 because pin 9 connects to the RF6 pin of the dsPIC30F4011 on the DSP Musicolour main board. Because this pin can sometimes function as an output, the resistor is used to limit the current into the data output pin of IRD2.

Construction

The Musicolour IrDA PC board is code 807 and measures 61mm × 20mm. This board is available from the *EPE PCB Service.* This is a simple PC board that should take a matter of minutes to build. Fig.2 shows the parts layout.

Inspect the board for any hairline cracks or unintended shorts before beginning the assembly. If you are satisfied that the PC board is good, begin by installing the five wire links.

Once that is done, install the six resistors. The resistor's values can be checked with a DMM (digital multimeter) before you insert them on the PCB.

After soldering these, you can solder in the capacitors. Start with the two

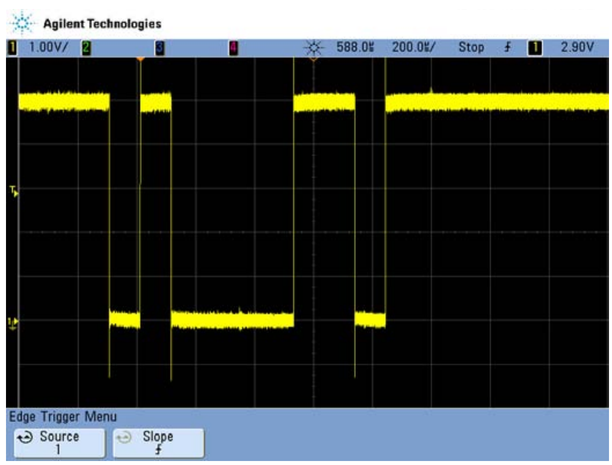
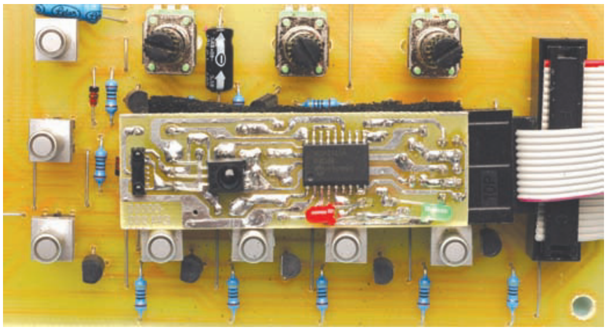
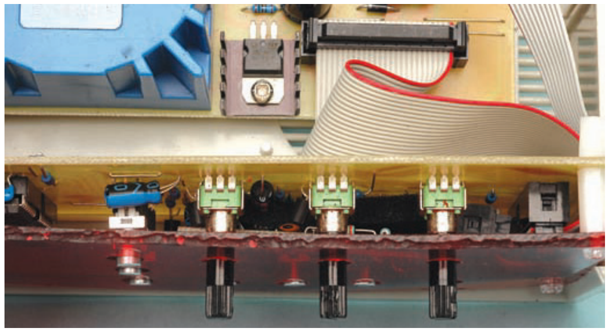


Fig.3: oscilloscope screen grab showing the NRZ encoding for a typical RS232 signal at the PHY.



The IrdA board is sandwiched between the DSP Musicolour display board and the red acrylic front panel, with a piece of non-conductive foam holding it in place.



Here's what it looks like from above – in this photo you can mostly see the black foam. The connecting cable curves around the edge of the display PC board.

ceramic capacitors near the crystal, then install the small monolithic one. Finally, install the larger electrolytic capacitor, which must be oriented correctly, as shown on the component overlay.

Solder in the crystal so that it sits flush with the PC board. The top layer components (except the IDC header) should now look like that in the PC board top layer photograph.

Now turn the board over to the bottom layer (where the tracks are). There are two SMD (surface mount devices) on the bottom layer – the MCP2140A (IC1) and the TFDU4300 (IRD1).

Soldering the SMD ICs

You will need a magnifying lamp (or glass with good light), a fine-tipped soldering iron and a steady hand. You should start with IC1 because it is of relatively large pitch. Place it on its pads, and be sure it is oriented correctly.

Once it is in place, solder pin 18 by applying heat and a little solder. Once that is done, solder pins 8 and 9 (diagonally opposite pin 18).

The IC should then be properly anchored and not able to move. Proceed to solder the remaining 15 pins. The result should be as shown in the photograph.

Now comes the hardest part. You need to solder in the IrDA transceiver, which has a finer pitch. Place it on its pads and hold it in place while applying heat and a very small amount of solder to pin 1.

You then solder in pin 8 in the same way, before soldering in the remaining pins. Apply heat and solder each pin quickly before moving on to the next pin. Do not apply too much heat as that can damage the plastic case as well as the integrated circuit itself.

Don't worry if you get solder bridges between adjacent pins, as these can be removed by using solder wick. Carefully inspect your soldering, preferably using an illuminated magnifier or loupe, and if you find any bridges, remove them. Refer to the *EPE* article on soldering SMD components in July 2010 for more details.

Now solder in the infrared receiver module IRD2. You should aim for around 7mm of lead, which will allow you to bend the module down 90° once it has been soldered, so that it sits flush with the PC board (as we have shown in the close-up photo).

The two LEDs are similarly bent down 90° after soldering. Make sure that they are oriented correctly.

The last thing to do is to solder in the 10-way IDC right-angled header. Again, check for solder bridges once it is soldered in place.

You can then connect the Musicolour IrDA board to the DSP Musicolour's main board using the 10-way ribbon cable. CON1 connects to CON3 on the DSP Musicolour main board, in exactly the same way as described in the article in the August 2010 issue.

We explained how to make a 26-way ribbon cable connecting the main board to the display board in the June

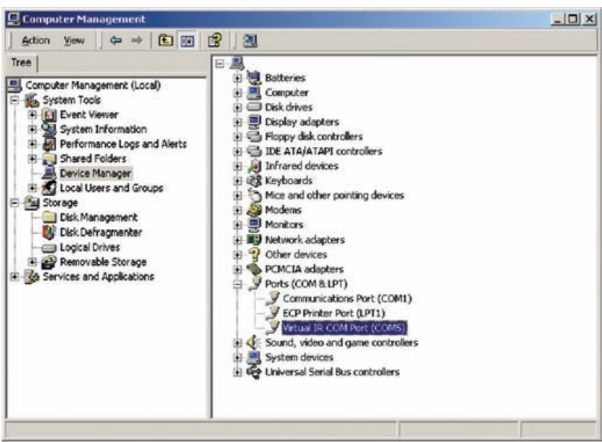


Fig.4: a screen shot from Windows' device manager showing the ircomm2k driver installed and recognised correctly.

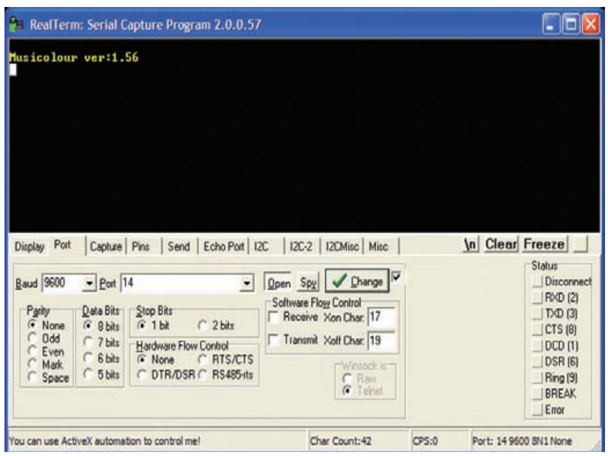
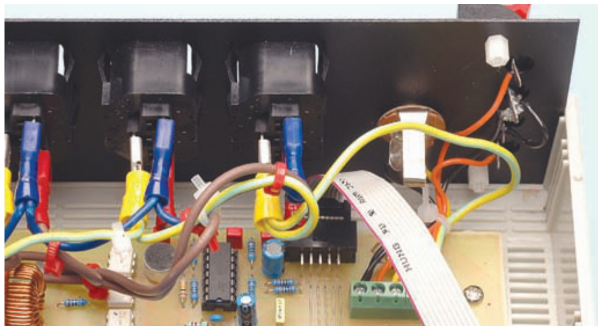


Fig.5: screen shot showing Realterm in action, communicating with the DSP Musicolour.

From the front, without any labelling on the acrylic sheet you can easily see the three main components (the two IRDs and the controller chip)



The opposite end of the ribbon cable connects to the same socket on the rear of the PC board, as used in the August 2010 article.

2010 issue (see Ribbon Cable Assembly). The 10-way ribbon cable used to connect the remote control board is made in the same way.

Your IrDA Board is now complete and ready for mounting in the DSP Musicolour front panel.

Disconnect power!

The first thing to do is disconnect power from the DSP Musicolour – pull the IEC plug out of its socket to make absolutely sure. Then, and only then, open the case.

Do not proceed unless you are absolutely sure you know what you are doing. Don't be tempted to connect power while the case is open – it is too dangerous.

Where it sits

The IrDA PC board fits between the red acrylic front panel and the display PC board. A piece of foam holds it in place and also insulates it from the components on the display board.

This is not an ideal mounting solution . . . but it is just about the only one! Because this board is an add-on, it was not catered for in the original DSP Musicolour design, but we think it's a practical addition and we've made the only mounting decision possible.

We have shown a close-up photo to show how it goes in. You can then close the case by screwing it shut.

Using the IrDA board with the DSP Musicolour

This add-on board gives the DSP Musicolour a wireless serial port you can use to communicate with a PC. It also allows the DSP Musicolour to be operated using an RC5 remote control, in the same manner explained in the August 2010 of *EPE*. You can define the remote control codes as explained in that article.

Software for Windows: the IRCOMM2K driver

Before communicating with the IrDA board, you will need to install a software driver implementing the IrCOMM protocol on Windows 2000 and XP.

It is a free download from www.ircomm2k.de/English/index.html, or via a link on the *EPE* website (**www.epemag.com**).

Follow the installation instructions. Note that your PC must have an IrDA port installed. This is commonly found on laptop computers and PDAs (but not all laptops will have an infrared port).

Most modern desktop motherboards also have supporting circuitry for it, but will probably lack the optical transceiver.

Using the IrDA serial port

Once you download the zipped **ircomm2k** driver, extract the files and run *setup.exe*. The install program will prompt you for the serial port number to install the virtual IR port. Choose a port number (say COM5) that will not interfere with any other (physical) serial ports implemented on your PC.

You should then disable the 'Wireless Image Transfer' in Windows. Go to Control Panel > Wireless Link and in the image transfer tab, unclick the box selecting 'Use Wireless Link to transfer images from a digital camera'. This needs to be disabled because the Windows service interferes with the **ircomm2k** driver.

Once that is done, you should reboot Windows. If the driver is installed correctly, you should be able to see it under Control Panel > System > Device Manager > Ports COM and LPT > Virtual IR COM Port (COM5), as shown in Fig.4.

Installing Realterm

The final thing to do is to use a terminal program to communicate with the Musicolour IrDA board. You can use Windows' hyperterminal if

Parts List – Musicolour IrDA Accessory

1 PC board, code 807, available from the *EPE PCB Service*, size 63mm × 21mm
1 3.6864MHz PC board mounting crystal (X1)
1 10-way PC board mounting IDC male connector (CON1)
1 10-way ribbon cable, approx. 250mm long fitted with female line sockets

Semiconductors
1 MCP2140A (IC1)
1 TFDU-4300 infrared transmit/receive module (IRD1)
1 Infrared receiver (eg Jaycar ZD-1952) (IRD2)
1 3mm green LED (LED1)
1 3mm red LED (LED2)

Capacitors
1 22µF 16V radial electrolytic
1 100nF ceramic
2 22pF ceramic

Resistors (0.25W, 1%)
1 47Ω 3 470Ω 2 10kΩ

How to modify the PC board to add an infra-red serial port to a microcontroller project

As we mentioned before, this PC board was designed to interface with the DSP Musicolour main board. But it can easily be modified to add a serial port to your next microcontroller project.

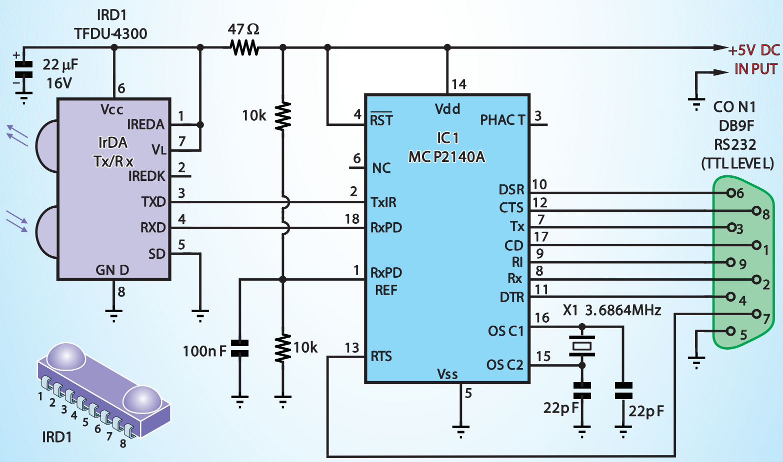
The modified circuit diagram below shows a typical application. The levels at CON1 are only TTL levels, adequate for interfacing directly to most microcontrollers implementing a UART.

Note that if you wish to interface the modified board directly to a PC, and need true RS232 voltage levels, you will need to add a MAX232 or similar IC to translate the TTL levels at CON1 to true RS232 levels (this is not shown in the circuit diagram).

The host (ie, the microcontroller) should only send data to the MCP2140A when CTS (Clear To Send) is low.

On the other hand, the host should drive DTR (Data Terminal Ready) low when it is ready to receive data from the MCP2140A.

The host can then send and receive data from the MCP2140A through the Tx and Rx pins (encoded as NRZ) ultimately to the connected IrDA-enabled PC or PDA (confusingly this is also a host, ie, the IrDA host!).



MODIFIED IRDA CIRCUIT

Use this modified circuit to add a wireless serial port to virtually any microcontroller project. Unlike the circuit used specifically to interface to the DSP Musicolour main board, this circuit emulates the full serial port rather than just the Rx and Tx signals. This can be used for handshaking between the microcontroller and IC1.

you wish, available under Start > Accessories > Communications > Hyperterminal.

Another good program to use is the freely available realterm. Download it from **http://realterm.sourceforge.net/**

Once that is installed, you can establish a link with the Musicolour IrDA board using COM5 (or whatever number for the virtual IR port you chose in the installation step above).

You should set the encoding to 8 bits, 1 stop bit, no parity, 9.6Kbps. As soon as you open Realterm and start typing characters, the green LED (LED1) on the IrDA board will light, indicating that a valid connection has been established.

Remember that you need to position your PC or laptop so that its infrared transceiver is in the line of sight of IRD1 and within 1m or so.

The characters you type will then be sent via the infrared link to the Musicolour IrDA board and onto the UART on the main board of the Musicolour (ie, on the dsPIC30F4011 microcontroller). A typical screen shot is shown in Fig.5.

In the DSP Musicolour menu system, you can go to the CONSOLE > COM submenu. There the DSP Musicolour will display the received characters from the serial port and echo back the same character. You should do this to test that the IrDA board is working correctly.

As you type your characters in Realterm, you should see them appear on the dot matrix display of the DSP Musicolour.

How to upgrade the firmware of the DSP Musicolour

If there are some aspects of the DSP Musicolour's firmware which you'd like to change – and you have the knowlege to do so – it can can be upgraded using this infrared port. Using Realterm, you can send a hex file to the DSP Musicolour to force it to reconfigure its flash memory using its RTSP server.

To do this, go to the ADVANCED > Write Mode menu and set it to 6 (thus allowing writing of the flash memory). Then go to the ADVANCED > Software Upgrade submenu. Once you enter that mode, the dot matrix display will go blank.

The DSP Musicolour will send a string to your Realterm window through the infrared link. You can then use realterm to send a hex file to the DSP Musicolour, which will reprogram itself and reset.

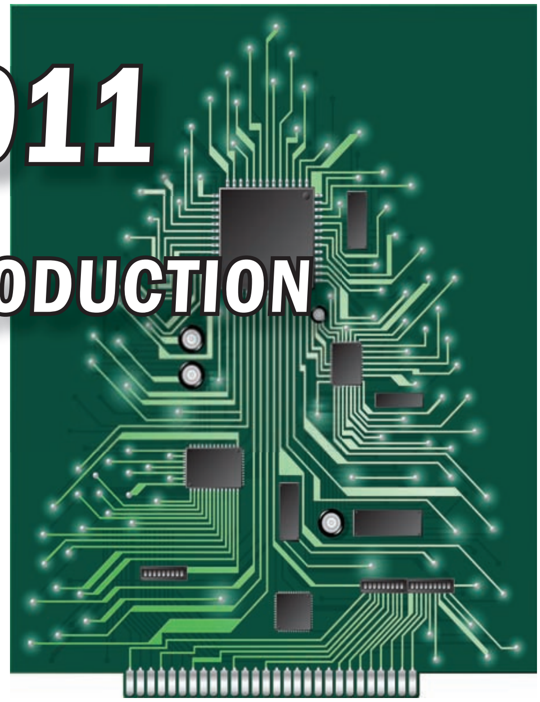
You should set the line delay to 40ms or higher. You then select the hex file you want to send and click send. Realterm will send each line and wait for the set line delay before sending another line.

If manually sending hex file lines, you must send the :00000001FF (end of file) line to indicate to the DSP Musicolour that programming is finished. Once the EOF (end of file) line is received by the RTSP server, the DSP Musicolour will reboot after 10 seconds and the new firmware version will be operational. ***EPE***

Reproduced by arrangement
with SILICON CHIP
magazine 2011.
www.siliconchip.com.au

TEACH-IN 2011

A BROAD-BASED INTRODUCTION TO ELECTRONICS



Part 8: Analogue Circuit Applications

By Mike and Richard Tooley

Our Teach-In series is designed to provide you with a broad-based introduction to electronics. We have attempted to provide coverage of three of the most important electronics units that are currently studied in many schools and colleges in the UK. These include Edexcel BTEC Level 2 awards, as well as electronics units of the new Diploma in Engineering (also at Level 2). The series will also provide the more experienced reader with an opportunity to 'brush up' on specific topics with which he or she may be less familiar.

Each part of our Teach-In series is organised under five main headings; Learn, Check, Build, Investigate and Amaze. Learn will teach you the theory, Check will help you to check your understanding, and Build will give you an opportunity to build and test simple electronic circuits. Investigate will provide you with a challenge which will allow you to further extend your learning, and finally, Amaze will show you the 'wow factor'!

IN LAST month's instalment of *Teach-In 2011*, we introduced you to the highly versatile 555 integrated circuit timer. We showed you how you can quickly and easily design circuits that will produce time delays from a few hundred nanoseconds to several hundred seconds, and square wave pulses of given frequency, period and duty cycle.

In this instalment, we introduce some practical applications of analogue circuits, including active and passive filters and tone control circuits. In ***Learn*** we will show you how circuits can be designed so that they accept or reject signals within a specified band of frequencies, and how the shape of the frequency response can be altered in order to modify and enhance the sound produced by an amplifier.

We also introduce decibels (dB) as a means of defining gain and loss in an analogue electronic system. ***Build*** and ***Investigate*** extend this further with a detailed look at some practical filter circuits. Finally, in ***Amaze*** we look at the range of signals found in radio and television.

Learn

Attenuators

Attenuators provide us with a means of reducing the level of a signal present in an analogue circuit. They provide the opposite of gain, and we refer to it as *attenuation*. In order to produce loss or attenuation we only need a network of passive components and, if signals at all frequencies are to be attenuated by the same amount, we only need to use resistors in our network. Several different types of network are possible, including the basic T and π-networks shown in Fig.8.1.

In order to work correctly (ie, provide the required amount of attenuation) an attenuator needs to be *matched* to the system in which it is used. This simply means ensuring that the impedance of the source, as well as that of the load, matches the characteristic impedance of the attenuator. In this condition, we say that an attenuator is correctly *terminated*. Fig.8.2 illustrates this concept.

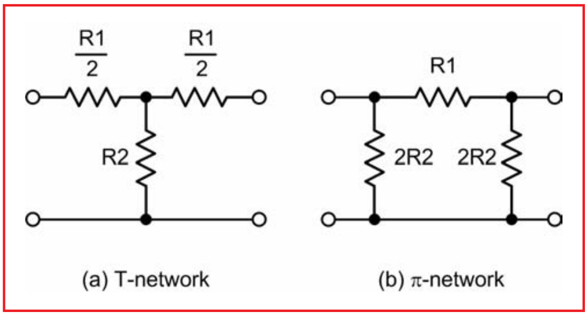


Fig.8.1. Basic T and π-network attenuators

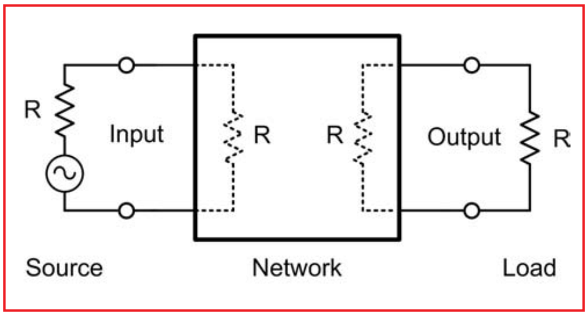


Fig.8.2. A matched network

Before we take a look at the operation of two simple forms of attenuator, it is worth pointing out that the impedances used in attenuators are always pure resistances. The reason for this is that an attenuator must provide the same attenuation at all frequencies and the inclusion of reactive components (inductors and/or capacitors) would produce a non-linear attenuation/frequency characteristic.

Balanced/unbalanced

The simple T and π-networks that we've just met can exist in two basic forms, *balanced* and un*balanced*. In the former case, none of the network's input and output terminals are connected directly to *common* or ground. The unbalanced and balanced forms of the basic T and π-networks are shown for comparison in Fig.8.3.

The networks shown in Fig.8.3 all have two *ports*. One port (ie, pair of terminals) is connected to the input, while the other is connected to the output. For convenience, many two-port networks are made symmetrical and they perform exactly the same function and have the same characteristics, regardless of which way round they are connected.

Please note!

It is conventional to express the values of the resistances present in an attenuator in terms of the effective series or parallel resistance. Thus, for example, the two series resistors in an unbalanced T-network attenuator are both labelled R1/2 where R1 is the effective series resistance.

Similarly, the two parallel resistors present in an unbalanced π-network are labelled 2R2 where R2 is the effective resistance of the two components when connected in parallel. We will be adopting a similar convention when we label the circuits used for filters.

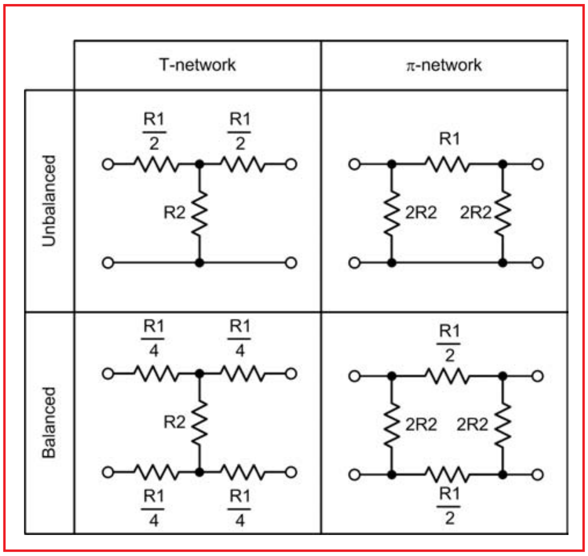


Fig.8.3. Balanced and unbalanced forms of the T and π-networks

Filters

Filters provide us with a means of passing or rejecting signals within a specified frequency range. Filters are used in a variety of applications, including amplifiers, radio transmitters and receivers. They also provide us with a means of reducing noise and unwanted signals that might otherwise be passed along power lines.

Filters are usually described according to the range of frequencies that they will accept or reject. The following types are possible:

- Low-pass
- High-pass
- Band-pass
- Band-stop.

Filters can also be categorised as either *passive* or *active*, depending on whether they are based on networks of passive components (ie, resistors, capacitors and inductors) or active components (ie, transistors and operational amplifiers) working together with resistors, capacitors and/or inductors.

The symbols used to represent these four types of filter in block schematic diagrams are shown in Fig.8.4.

Low-pass filters

Low-pass filters exhibit very low attenuation of signals below their specified *cut-off frequency*. Beyond the cut-off frequency, they exhibit increasing amounts of attenuation, as shown in Fig.8.5.

A simple *C-R* low-pass filter is shown in Fig.8.6. The cut-off frequency for the filter occurs when the output voltage has fallen to

0.707 of the input value. This occurs when the reactance of the capacitor, X_C, is equal to the value of resistance, R. Using this information we can determine the value of cut-off frequency, f, for given values of C and R:

Since

$$R = X_C$$

or

$$R = \frac{1}{2\pi fC}$$

from which:

$$f = \frac{1}{2\pi CR}$$

where f is the cut-off frequency (in Hz), C is the capacitance (in F), and R is the resistance (in Ω).

High-pass filters

High-pass filters exhibit very low attenuation of signals above their specified cut-off frequency. Below the cut-off frequency, they exhibit increasing amounts of attenuation, as shown in Fig.8.7.

A simple C-R high-pass filter is shown in Fig.8.8. Once again, the cut-off frequency for the filter occurs when the output voltage has fallen to 0.707 of the input value. This occurs when the reactance of the capacitor, X_C, is equal to the value of resistance, R. Using this information we can determine the value of cut-off frequency, f, for given values of C and R:

Since

$$R = X_C$$

or

$$R = \frac{1}{2\pi fC}$$

and once again:

$$f = \frac{1}{2\pi CR}$$

where f is the cut-off frequency (in Hz), C is the capacitance (in F), and R is the resistance (in Ω).

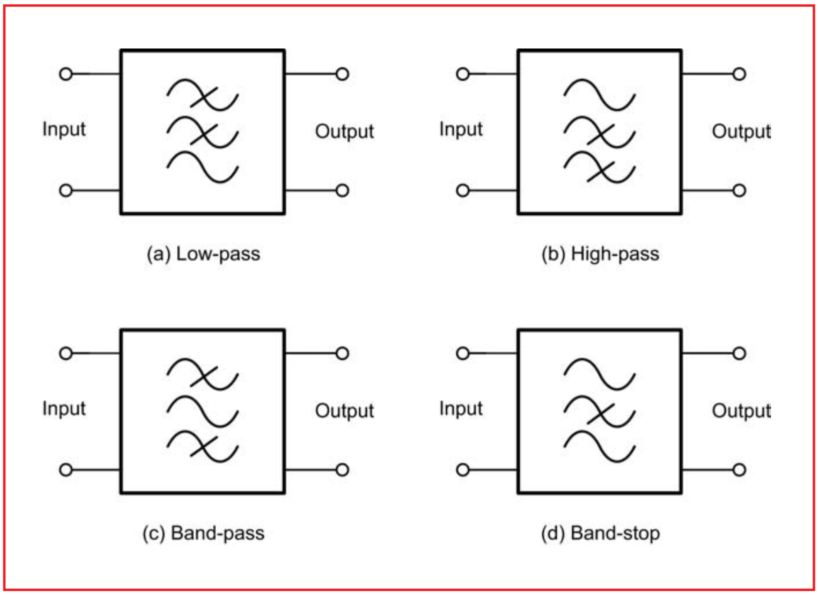


Fig.8.4. Symbols used to represent filters: a) low-pass; b) high-pass; c) band-pass and d) band-stop

Please note!

The term ‘cut-off’ can be a bit misleading because it might imply that a filter will produce no output at all beyond a certain point. This is not the case. The response of a practical filter will simply ‘roll-off’ beyond the cut-off frequency and one of the most important characteristics of a filter is the rate at which this roll-off occurs.

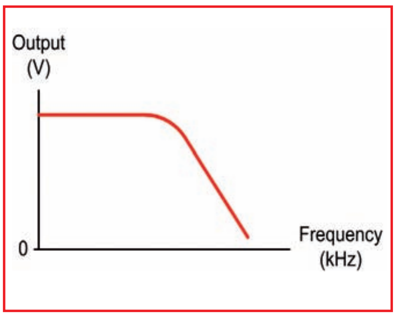


Fig.8.5. Frequency response for a low-pass filter

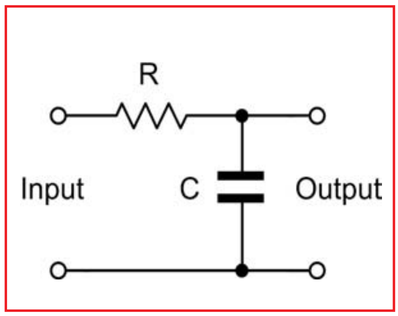


Fig.8.6. A simple C-R low-pass filter

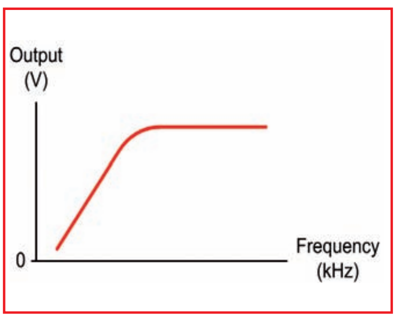


Fig.8.7. Frequency response for a high-pass filter

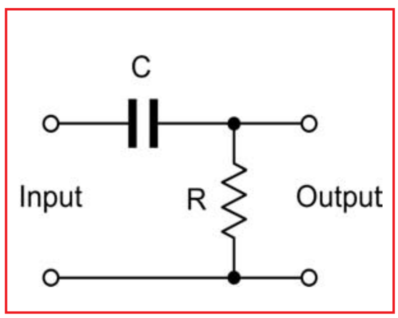


Fig.8.8. A simple C-R high-pass filter

Example 1

A simple *C-R* low-pass filter has C = 100nF and R = 10kΩ. Determine the cut-off frequency of the filter.

We can find the cut-off frequency using:

$$f = \frac{1}{2\pi CR}$$

$$= \frac{1}{6.28 \times 100 \times 10^{-9} \times 10 \times 10^{4}}$$

$$= \frac{100}{6.28} = 15.9\text{Hz}$$

Example 2

A simple *C-R* low-pass filter is to have a cut-off frequency of 1kHz. If the value of capacitance used in the filter is to be 47nF determine the value of resistance.

Re-arranging the equation for cut-off frequency gives:

$$R = \frac{1}{2\pi fC}$$

$$= \frac{1}{6.28 \times 1 \times 10^{3} \times 47 \times 10^{-9}}$$

$$= \frac{10^{6}}{295.16} = 3.39\,\text{k}\Omega$$

Band-pass filters

Band-pass filters exhibit very low attenuation of signals within a specified range of frequencies (known as the *pass-band*), and increasing attenuation outside this range. This type of filter has two cut-off frequencies; a *lower cut-off frequency* (f_1) and an *upper cut-off frequency* (f_2). The difference between these frequencies ($f_2 - f_1$) is known as the *bandwidth* of the filter. The response of a band-pass filter is shown in Fig.8.9.

A simple *L-C* band-pass filter is shown in Fig.8.10. This circuit uses an *L-C* resonant circuit and is often referred to as an *acceptor circuit*.

The frequency at which the band-pass filter in Fig.8.10 exhibits minimum attenuation occurs when the circuit is *resonant*, ie, when the reactance of the capacitor, X_C, is equal to the value of the reactance of the inductor, X_L. This information allows us to determine the value of frequency at the centre of the pass-band, f_0:

$$X_C = X_L$$

thus

$$\frac{1}{2\pi f_0 C} = 2\pi f_0 L$$

from which

$$f_0^{\,2} = \frac{1}{4\pi^2 LC}$$

and thus

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

where f_0 is the resonant frequency (in Hz), L is the inductance (in H) and C is the capacitance (in F).

The bandwidth of the band-pass filter is determined by its *quality factor* (or *Q-factor*). This, in turn, is largely determined by the loss resistance, R, of the inductor (recall that a practical coil has some resistance as well as inductance). The bandwidth is given by:

$$\text{Bandwidth} = f_2 - f_1 = \frac{f_0}{Q}$$

$$= \frac{2\pi f_0 L}{R}$$

where f_0 is the resonant frequency (in Hz), L is the inductance (in H), and R is the loss resistance of the inductor (in Ω).

Band-stop filters

Band-stop filters exhibit very high attenuation of signals within a specified range of frequencies (known as the *stop-band*) and negligible attenuation outside this range. Once again, this type of filter has two cut-off frequencies; *a lower cut-off frequency* (f_1) and an *upper cut-off frequency* (f_2). The difference between these frequencies ($f_2 - f_1$) is known as the *bandwidth* of the filter. The response of a band-stop filter is shown in Fig.8.11.

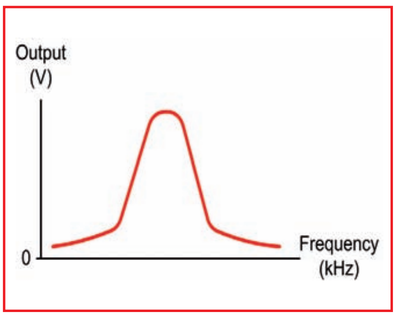


Fig.8.9. Frequency response for a band-pass filter

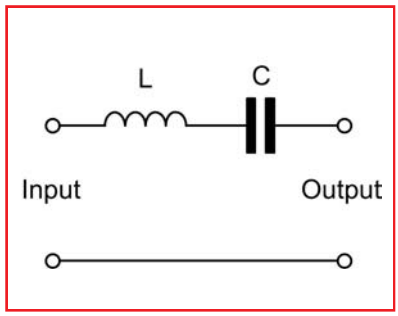


Fig.8.10. A simple L-C band-pass filter (or acceptor)

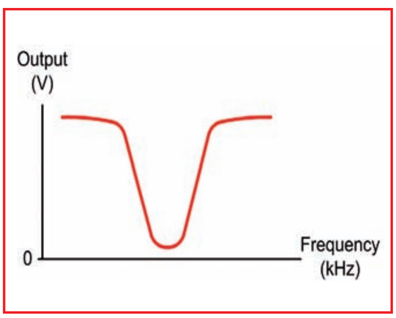


Fig.8.11. Frequency response for a band-stop filter

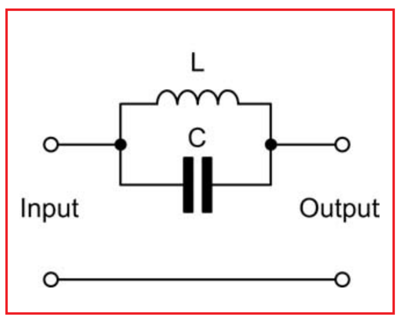


Fig.8.12. A simple L-C band-stop filter (or rejector)

A simple *L-C* band-stop filter is shown in Fig.8.12. This circuit uses an *L-C* resonant circuit and is referred to as a *rejector circuit*.

The frequency at which the band-stop filter in Fig.8.12 exhibits maximum attenuation occurs when the circuit is resonant, ie, when the reactance of the capacitor, X_C, is equal to the reactance of the inductor, X_L. This information allows us to determine the value of frequency at the centre of the pass-band, f_0:

$$X_C = X_L$$

thus

$$\frac{1}{2\pi f_0 C} = 2\pi f_0 L$$

from which

$$f_0^2 = \frac{1}{4\pi^2 LC}$$

and thus

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

where f_0 is the resonant frequency (in Hz), L is the inductance (in H) and C is the capacitance (in F).

As with the band-pass filter, the bandwidth of the band-pass filter is determined by its quality factor (or Q-factor). This, in turn, is largely determined by the loss resistance, R, of the inductor (recall that a practical coil has some resistance as well as inductance). Once again, the bandwidth is given by:

$$\text{Bandwidth} = f_2 - f_1 = \frac{f_0}{Q}$$

$$= \frac{2\pi f_0 L}{R}$$

where f_0 is the resonant frequency (in Hz), L is the inductance (in H), and R is the loss resistance of the inductor (in Ω).

Example 3

A simple acceptor circuit uses L = 2mH and C = 1nF. Determine the frequency at which minimum attenuation will occur.

The frequency of minimum attenuation will be given by:

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

$$= \frac{1}{2\pi\sqrt{2\times10^{-3}\times1\times10^{-9}}}$$

$$= \frac{10^6}{8.88} = 112.6\,\text{kHz}$$

Example 4

A 15kHz rejector circuit has a Q-factor of 40. Determine the bandwidth of the circuit.

The bandwidth can be found from:

$$\text{Bandwidth} = \frac{f_0}{Q} = \frac{15\times10^3}{40}$$

$$= 375\,\text{Hz}$$

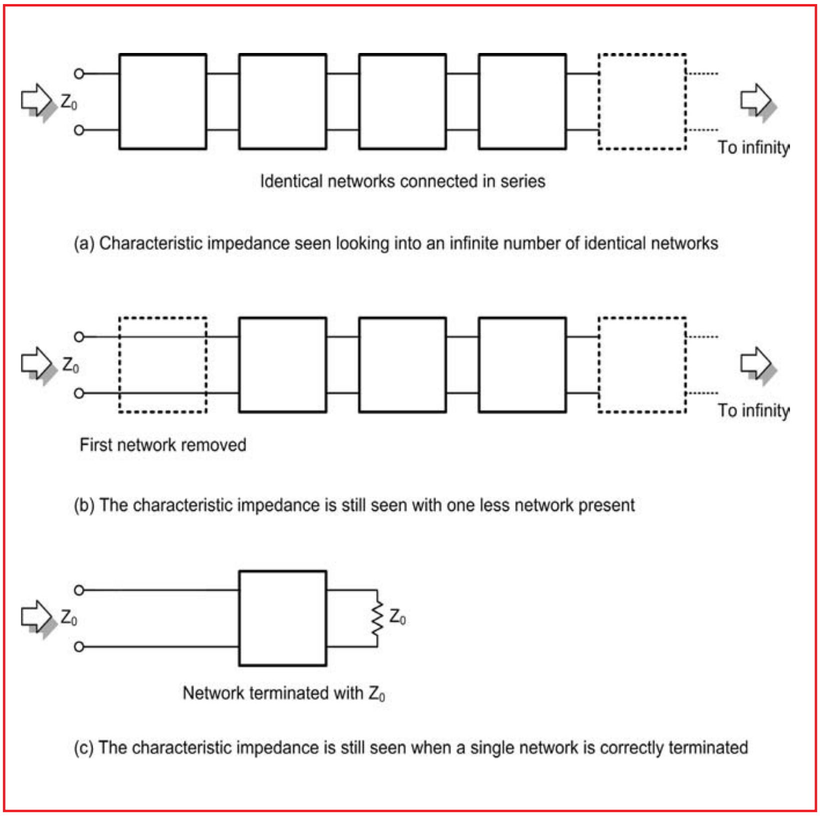


Fig.8.13. The characteristic impedance (Z_0) of a network is determined by the values of resistance (or impedance) within the network – see text

Termination, matching and characteristic impedance

For the performance of a filter or an attenuator to be predictable we need to take into account the input (*source*) and output (*load*) impedances. These impedances are said to *terminate* the filter – without taking them into account the performance can be somewhat unpredictable!

When a filter or attenuator is correctly terminated it is said to be matched. Analogue systems are often designed so that they have a particular input/source and output/load impedance. In many audio systems the impedance chosen is 600Ω, but in radio frequency (RF) applications impedances of 50Ω, 75Ω or 300Ω are common.

It is often convenient to analyse the behaviour of a signal transmission path in terms of a number

of identical series connected networks. One important feature of any network is that, when an infinite number of identical symmetrical networks are connected in series, the resistance (or impedance) seen looking into the network will have a definite value. This value is known as the *characteristic impedance* of the network

Take a look at Fig.8.13. In Fig.8.13(a) an infinite number of identical networks are connected in series. By definition, the impedance seen looking into this arrangement will be equal to the characteristic impedance, Z_0.

Now suppose that we remove the first network in the chain, as shown in Fig 8.13(b). To all intents and purposes, we will still be looking into an infinite number of series- connected networks. Thus, once again, we will see an impedance equal to Z_0 when we look into the network.

Finally, suppose that we place an impedance of Z_0 across the output terminals of the single network that we removed earlier. This terminated network (see Fig.8.13(c) will behave exactly the same way as the arrangement in Fig.8.13(a). In other words, by correctly terminating the network in its characteristic impedance, we have made one single network section appear the same as a series of identical networks stretching to infinity.

The characteristic impedance (Z_0) of a network is determined by the values of resistance (or impedance) within the network, as we shall see next.

More complex filters

The simple *C-R* and *L-C* filters that we have described in earlier sections have far from ideal characteristics. In practice, more complex circuits are used and a selection of these (based on matched *T-section* and *π-section* networks) are shown in Fig.8.14. The design equations for these circuits are as follows:

Characteristic impedance:

$$Z_0 = \sqrt{\frac{L}{C}}$$

Cut-off frequency:

$$f_C = \frac{1}{2\pi\sqrt{LC}}$$

Inductance:

$$L = \frac{Z_0}{2\pi f_C}$$

Capacitance:

$$C = \frac{1}{2\pi f_C Z_0}$$

where Z_0 is the characteristic impedance (in Ω), f_C is the cut-off frequency (in Hz), L is the inductance (in H), and C is the capacitance (in F).

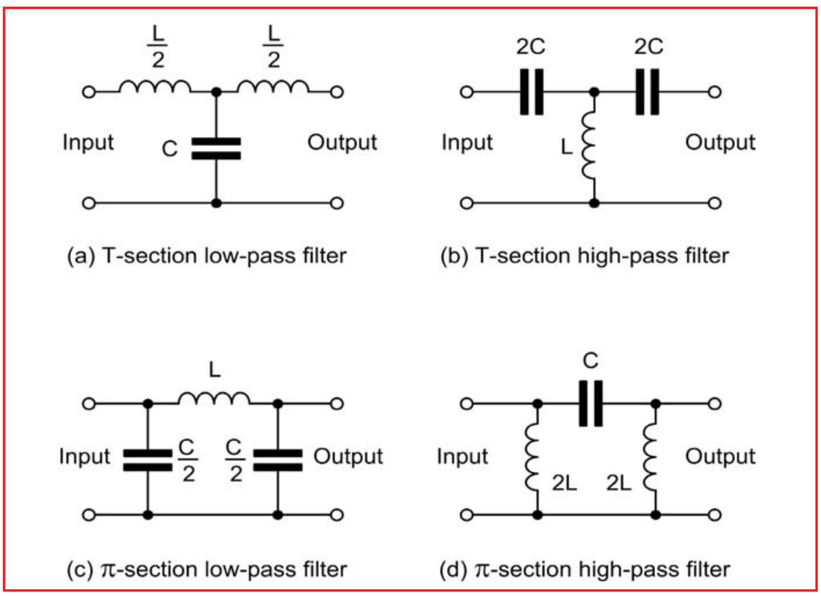


Fig.8.14. Improved T-section and π-section filters

Example 5

Determine the cut-off frequency and characteristic impedance for the filter network shown in Fig.8.15.

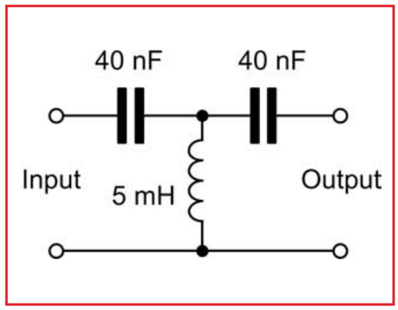


Fig.8.15. See Example 5 in text

Comparing the circuit shown in Fig.8.15 with that shown in Fig.8.14 shows that the filter is a high-pass type with L = 5mH and C = 20nF (note that the value of C is the effective series capacitance and is equivalent to the two 40nF capacitors connected in series).

Now

$$f_C = \frac{1}{2\pi\sqrt{LC}}$$

$$= \frac{1}{6.28\sqrt{5\times10^{-3}\times20\times10^{-9}}}$$

$$= \frac{10^5}{6.28} = 1.59\text{kHz}$$

and

$$Z_0 = \sqrt{\frac{L}{C}} = \sqrt{\frac{5\times10^{-3}}{20\times10^{-9}}} = \sqrt{\frac{5}{20}}\times10^3$$

$$= 0.5\times10^3 = 500\ \Omega$$

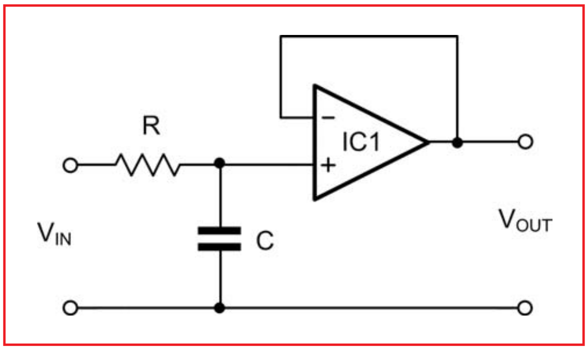


Fig.8.16. First-order active low-pass filter

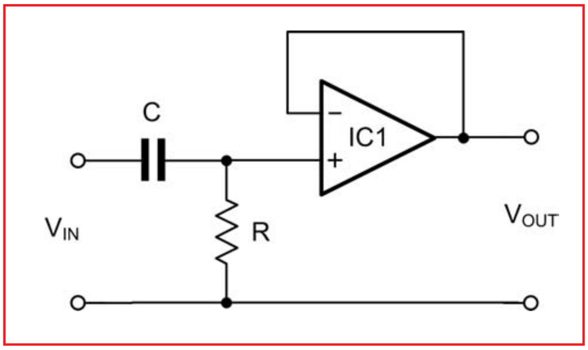


Fig.8.17. First-order active high-pass filter

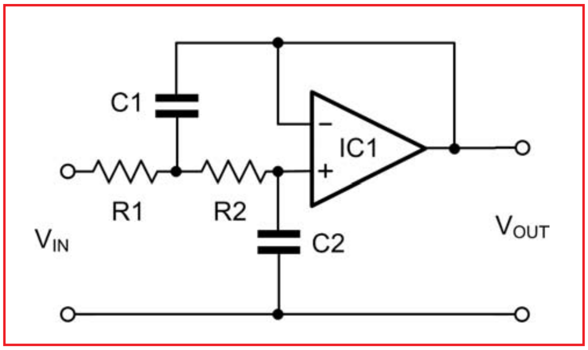


Fig.8.18. Second-order Sallen and Key active low-pass filter

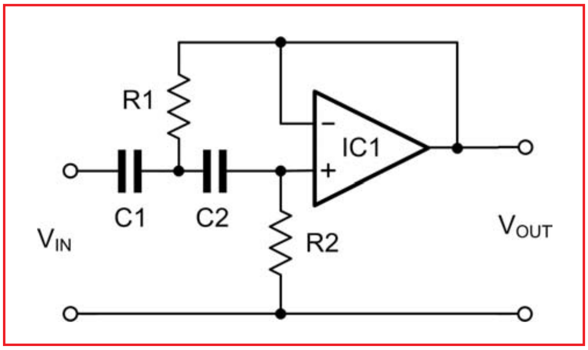


Fig.8.19. Second-order Sallen and Key active high-pass filter

Active filters

The simple *R-C* filters that we described earlier in Fig.8.6 and Fig.8.8 require a very low source impedance and a very high load impedance in order to behave in a predictable manner (ie, to satisfy the equation for cut-off frequency that we met earlier). One way of improving the performance of these filters is to terminate them using a unity gain operational amplifier buffer, as shown in Fig.8.16 and Fig.8.17. These circuits maintain the predicted frequency response, but the rate at which the output voltage falls above cut-off may be insufficient for many applications.

Fortunately, we can easily solve this problem by exploiting the gain available from the operational amplifier. Fig.8.18 and Fig.8.19 shows popular *second-order* Sallen and Key low-pass and high-pass filters. These filters roll-off at twice the rate that can be obtained with the simple *first-order* filters shown in Fig.8.16 and Fig.8.17. Later, in ***Build*** you will have the opportunity to build and test these circuits.

The cut-off frequency of the second-order filters shown in Fig.8.18 and Fig.8.19 is given by:

Decibels

One of the most important parameters of an analogue circuit is the amount of gain or loss that it provides. Gain can be expressed in various ways, but basically it is just the ratio of output to input expressed in terms of either voltage, current or power. Since gain and loss can sometimes be quite large we often use a logarithmic scale to express our ratios.

This measurement is based on decibels (dB), where one decibel is equivalent to one tenth of a Bel (the logarithm of the voltage, current or power ratio). In case this is beginning to sound a little complicated we have summarised all of this in Table 8.1.

Table 8.1. Gain or loss expressed in decibels of voltage, current and power

Basis of measurement	*Gain or loss as a ratio*	*Gain or loss expressed in decibels (dB)*
Voltage	$\frac{V_{out}}{V_{in}}$	$20\log_{10}\left(\frac{V_{out}}{V_{in}}\right)$
Current	$\frac{I_{out}}{I_{in}}$	$20\log_{10}\left(\frac{I_{out}}{I_{in}}\right)$
Power	$\frac{P_{out}}{P_{in}}$	$10\log_{10}\left(\frac{P_{out}}{P_{in}}\right)$

$$f_0 = \frac{1}{2\pi\sqrt{C1R1 \times C2R2}}$$

When $C1 = C2 = C$ and $R1 = R2 = R$ this equation simplifies to:

$$f_0 = \frac{1}{2\pi CR}$$

Please note!

The first-order filters that we met in Fig.8.16 and Fig.8.17 roll-off their response at the rate of 6dB per octave, while the second-order filters shown in Fig.8.18 and Fig.8.19 have a response that rolls-off at 12dB per octave. Note that 'per octave' simply means a doubling or halving of frequency.

Example 6

An amplifier used in a matched system produces an output voltage of 2V for an input of 20mV. What is the voltage gain of the amplifier when expressed in decibels?

The voltage gain, A_V, can be calculated from:

$$A_V = 20\log_{10}\left(\frac{V_{out}}{V_{in}}\right)$$

$$= 20\log_{10}\left(\frac{2}{0.02}\right)$$

$$= 20\log_{10}(100) = 20 \times 2 = 40\text{dB}$$

Example 7

A 6dB matched attenuator is used to reduce the power level produced by an amplifier that produces an output of 1.6W. What power will appear at the output of the attenuator?

Rearranging the equation for power gain in Table 8.1 produces:

$$\text{Now } A_P = 10\log_{10}\left(\frac{P_{out}}{P_{in}}\right)$$

Rearranging this expression gives:

$$\frac{A_P}{10} = \log_{10}\left(\frac{P_{out}}{P_{in}}\right)$$

Taking inverse logarithms (ie, antilogs) of both sides we arrive at:

$$\text{antilog}_{10}\left(\frac{A_P}{10}\right) =$$

$$\text{antilog}_{10}\left[\log_{10}\left(\frac{P_{out}}{P_{in}}\right)\right] = \frac{P_{out}}{P_{in}}$$

From which:

$$\text{antilog}_{10}\left(\frac{-6}{10}\right) =$$

$$\text{antilog}_{10}(-0.6) = \frac{P_{out}}{P_{in}}$$

(Note that we have inserted a minus sign in order to indicate a *loss* of 6dB)

Rearranging this expression gives:

$$P_{out} = P_{in} \times \text{antilog}_{10}(-0.6) =$$

$$1.6 \times 0.25 = 0.4\text{W}$$

Please note!

When plotting the frequency response of a filter we often use a logarithmic scale for frequency because this allows a much wider range of values to be accommodated and avoids cramping.

The term 'cut-off' can be a bit misleading because it might imply that a filter will produce no output at all beyond a certain point. This is not the case. The response of a practical filter will simply 'roll-off' beyond the cut-off frequency and one of the most important characteristics of a filter is the rate at which this roll-off occurs.

Check – How do you think you are doing?

8.1. Identify each of the circuits shown in Fig.8.20

8.2. Sketch the circuit of (a) a simple *L-C* acceptor circuit, and (b) a simple *L-C* rejector circuit.

8.3. A simple R-C high-pass filter has R = 5kΩ and C = 15nF. Determine the cut-off frequency of the filter.

8.4. The output of a low-pass filter is 2V at 100Hz. If the filter has a cut-off frequency of 1kHz what will the approximate output voltage be at this frequency?

8.5. An *L-C* tuned circuit is to be used to reject signals at 15kHz. If the value of capacitance is 2.2nF determine the required value of inductance.

8.6. Sketch the frequency response for (a) a simple *L-C* acceptor circuit, and (b) a simple *L-C* rejector circuit.

8.7. An attenuator is used in a matched system. If the output of the attenuator is 30mV for an input of 180mV what loss does it produce? Express your answer in dB.

8.8. An amplifier used in a matched system provides a power gain of 26dB. What input power is required to produce an output power of 16W?

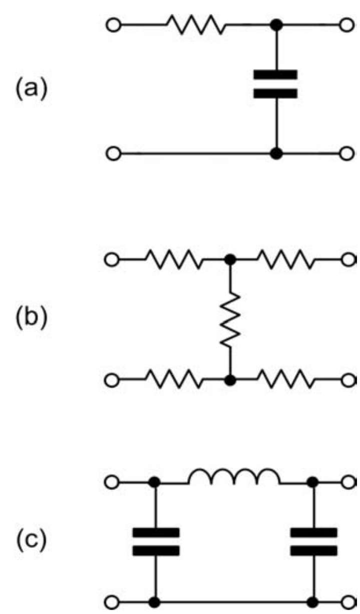


Fig.8.20. See Question 1

Build – The Circuit Wizard way

WE ARE now going to try out some practical filter circuits, and see how they behave when we apply different signals to them.

One of the features that Circuit Wizard lacks that we often find in higher-end electronics packages is the ability to directly carry out AC analysis to a given circuit. Usually, this would involve modelling the circuit, entering the signal characteristics and limits, then letting the software 'sweep' through the frequency range and plot the output amplitude and phase.

There are a number of useful applications that can do this, for example 5Spice Analysis (**www.5spice.com**). Be warned though, these software packages are often rather difficult to use unless you are familiar with similar SPICE analysis programmes.

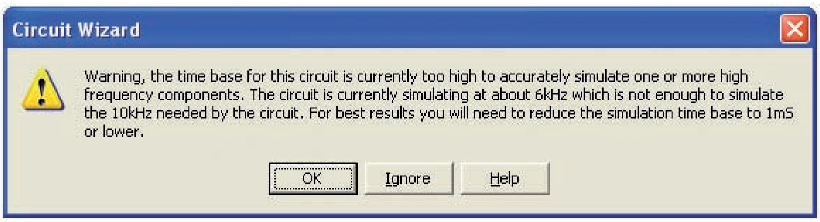


Fig.8.21. Simulation speed warning

Although Circuit Wizard can't do the analysis for us automatically, it still does a great job of modelling filter circuits as we will see later. We can then bring our results together and plot our own frequency curves. In fact, this is a great way to understand what's really going on and what happens to the signals as we vary the frequency of the input.

Simulations

Circuit Wizard carries out literally thousands of mathematical calculations in the background in order to show you how the circuit operates over time. However, when we are working with higher frequency signals that change very rapidly, it just can't keep up in real-time. Therefore, we need to slow down the simulation speed in order to give the software a chance to accurately simulate.

In the author's experience, the process of finding a suitable speed for a circuit to simulate is, to be honest, a bit of a fiddle. Therefore, you will need to experiment to some degree to get your traces looking right.

Speed trap

Under certain circumstances Circuit Wizard will warn you about accurate high speed simulation (see Fig.8.21). However, in practice it will happily present you with bizarre results with no warning. Fig.8.22 shows an example trace of a 1kHz sinewave simulated in real time!

Changing the simulation speed is achieved by clicking on 'Time:' found along the bottom grey bar, and selecting an appropriate timing (see Fig.8.23). Note that this only appears when the simulation is running.

Low-pass filter test circuit

Let's begin by looking at a first-order low-pass filter circuit. Enter the circuit shown in Fig. 8.24 below. This is an active filter circuit using an operational amplifier. Be sure to use terminals for the output terminals and voltage rails for the supply to the operational amplifier; getting this wrong is a common mistake that students make.

Please note that in order for our Circuit Wizard circuits to match the circuit diagrams you have seen in ***Learn*** you will need to 'mirror' the operational amplifier symbol so that

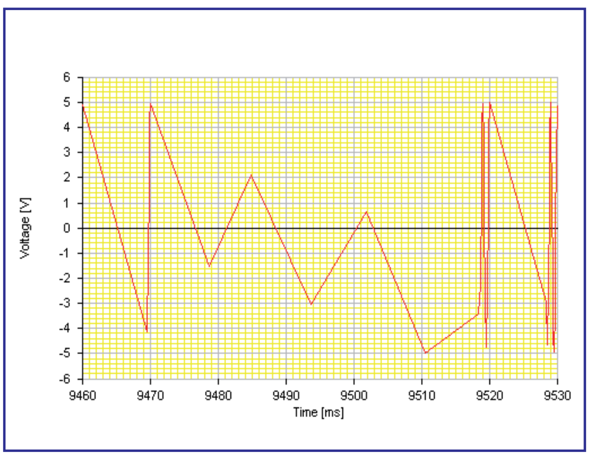
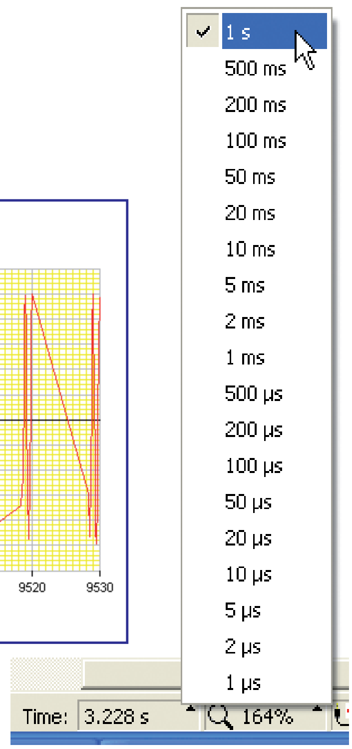


Fig.8.22. The bizarre result of simulating a high frequency circuit in real-time

Fig.8.23 (below). Changing simulation speed



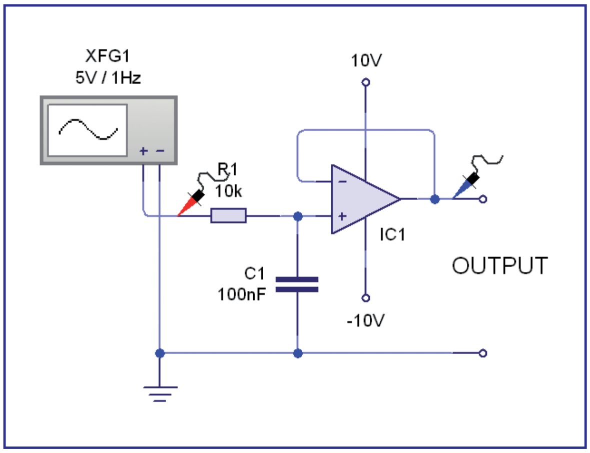


Fig.8.24. First order low-pass filter test circuit

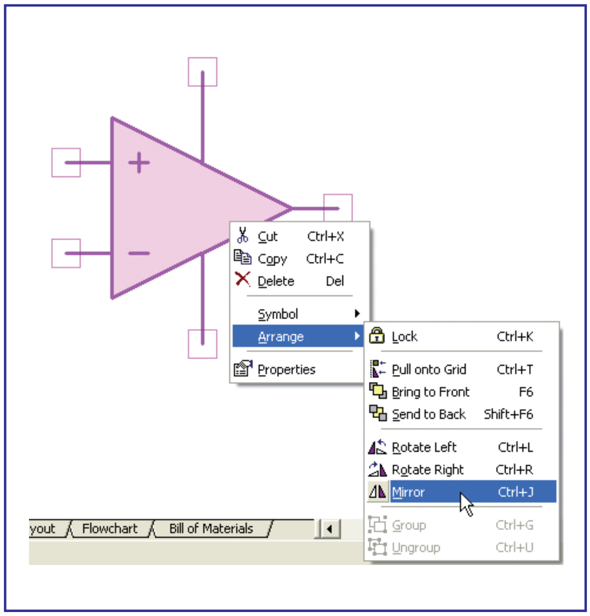


Fig.8.25. Mirroring the operational amplifier

the inverting ('-') input is at the top (see Fig.8.25).

Using your new knowledge from ***Learn*** you should be able to calculate the cut-off frequency to be around 159Hz. This means that we should expect it to happily pass low frequency signals below this frequency and reject high frequency signals.

In order to test this out we'll simulate the circuit with various frequencies and record the amplitude of the output. We can then plot this in Excel and see the characteristics of the filter.

Start by simulating the circuit with a 1Hz input frequency (ie, set the frequency of the function generator to 1Hz – Circuit Wizard will do this happily in real time.

You should alter the properties of the graph as follows; maximum: 6V, minimum: 6V, time: 200ms. Your trace should look similar to Fig.8.26. You should also notice that the output (blue) and input (red) are basically identical, meaning that the signal has passed directly through the filter unchanged.

Now change the frequency of the signal generator to 100Hz. You will also need to decrease the simulation speed and graph properties. These were 5ms and 2ms in the author's case, but you should experiment to get the best results. The resulting waveform is show in Fig.8.27. Notice that the amplitude has been reduced or attenuated to around 4.2V, and the output waveform has been delayed and is out of phase.

Experiment with various frequencies between 1Hz and 200Hz, recording your results. When you have a number of results plot them on a graph with frequency along the x-axis and amplitude along the y-axis. If you are using Excel to plot the graph, make sure that you select the 'scatter' graph type, as this will

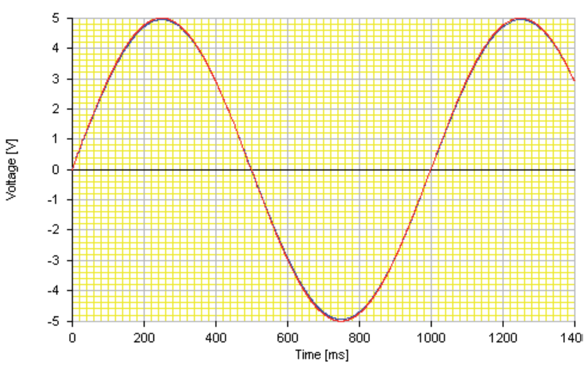


Fig.8.26. A 1Hz input trace – low-pass filter

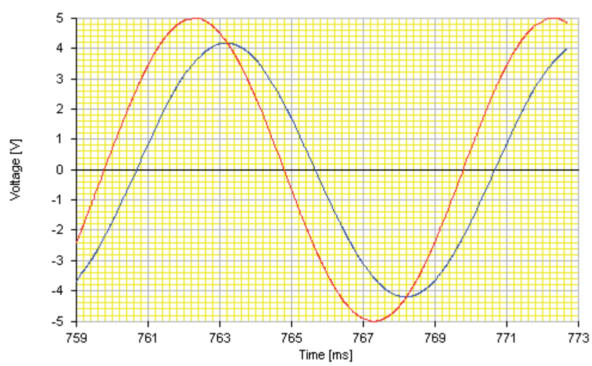


Fig.8.27. A 100Hz input trace – low-pass filter

Build – The Circuit Wizard way

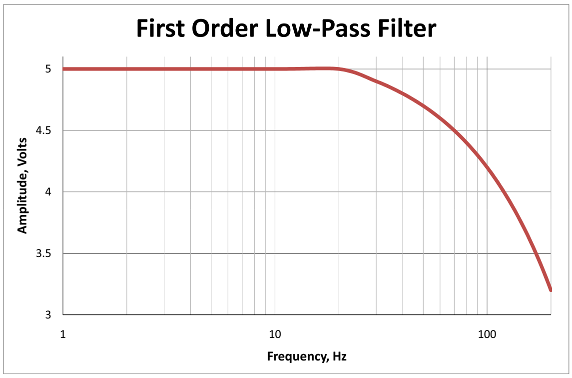


Fig.8.28. Graph showing the response of the low-pass first-order filter

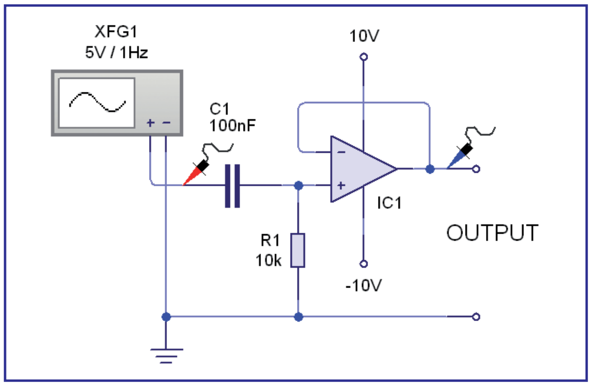


Fig.8.29. First-order high-pass filter test circuit

correctly plot the two values against each other. Fig.8.28 shows our results taking readings every 10Hz.

High-pass filter test circuit

Edit the low-pass filter circuit by essentially swapping the capacitor and resistor. You should now have the first-order high-pass filter shown in Fig.8.29.

Experiment to see how the output changes with different frequencies from 1Hz to 600Hz recoding your results and plotting them on a graph. You should find that in contrast to the low-pass filter, low frequencies are attenuated while higher frequencies are passed unaltered. You should also notice that the lower the frequency the higher the phase difference. Our results are shown in Fig.8.30.

Second-order filters

Now we're going to ramp things up a little and look at second-order filters. Fig.8.31 and Fig.8.32 show a low-pass and high-pass second-order filter respectively. Use your theory knowledge from ***Learn*** to calculate the cut-off frequency for each circuit and use this to help you select an appropriate frequency range to test the circuit. Simulate the circuit and collect a series of results in order to help you produce graphs for each circuit showing how they respond.

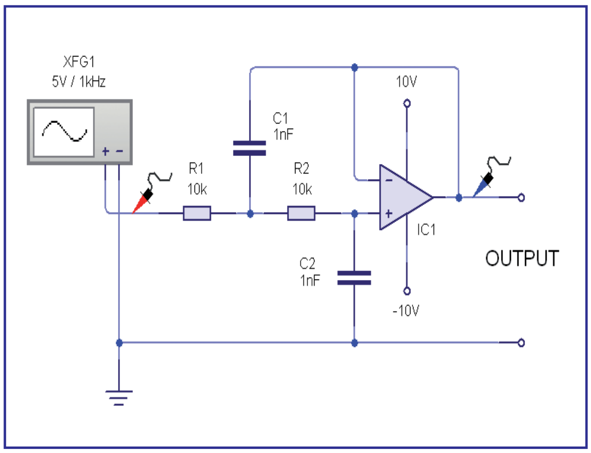


Fig.8.31. Second-order low-pass filter test circuit

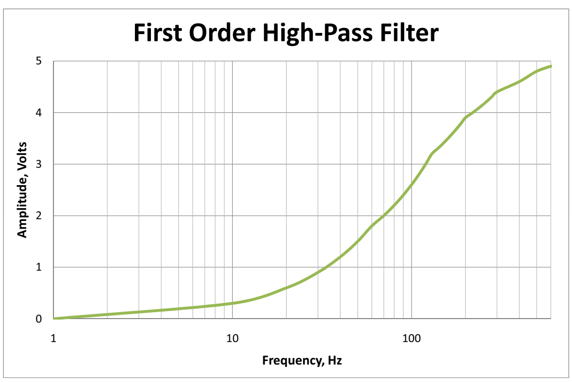


Fig.8.30. Graph showing the response of the high-pass first-order filter

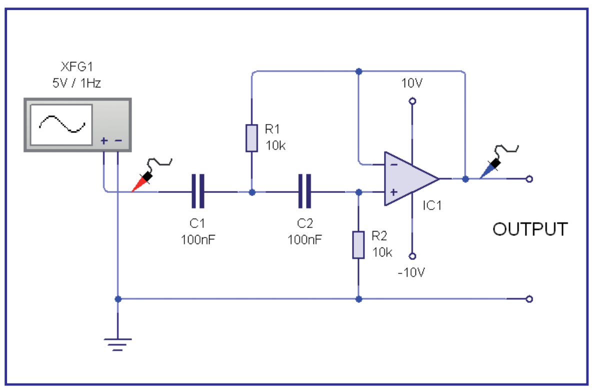


Fig.8.32. Second-order high-pass filter test circuit

Band-pass filter

Last, we are going to produce a band-pass filter using the two second-order filters. Enter the circuit shown in Fig.8.33. You may find it quicker to copy and paste your two second order circuits on to one sheet rather than drawing it from scratch. Finally, by altering the input frequency, monitor how the filter responds. Record your results and produce a frequency response graph; our example is shown in Fig.8.34.

Using everything that you've learnt, produce and test a filter circuit with a lower cut-off frequency of 800Hz and upper cut-off frequency of 8kHz. Prove your final design by creating a frequency response curve.

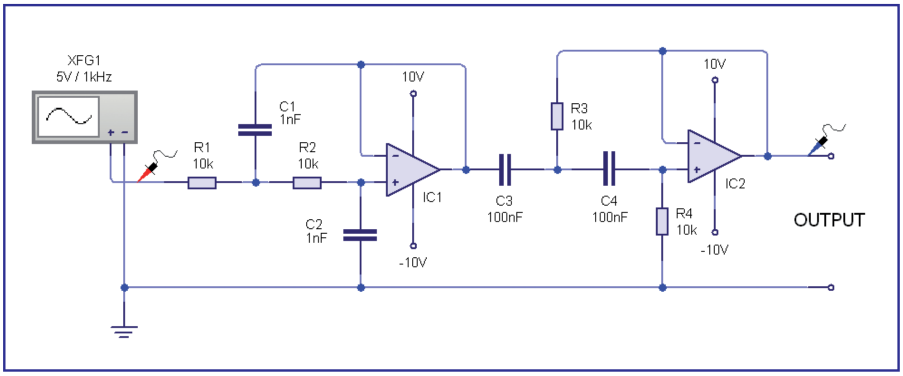


Fig.8.33. Band-pass filter test circuit

For more information, links and other resources please check out our Teach-In website at:
www.tooley.co.uk/teach-in

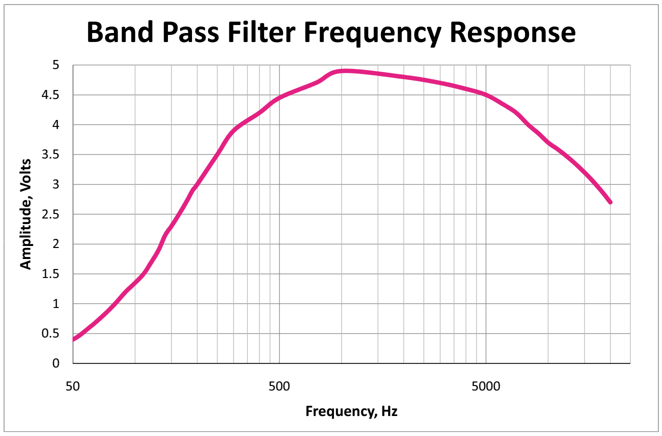


Fig.8.34 (right). Example band-pass filter frequency response graph

Answers to Check questions

8.1. a) Simple *C-R* unbalanced low-pass filter, (b) balanced T-network attenuator, (c) unbalanced low-pass π-network attenuator

8.2. See page 49

8.3. 2.12kHz

8.4. 1.41V

8.5. 51mH

8.6. See page 49

8.7 15.6dB

8.8 40mW

Investigate

Table 8.2.

Frequency (Hz)	20	40	70	100	200	700	1k	2k	4k	7k	10k	20k	40k	60k
Voltage gain (dB)	-3	+5	+12.5	+15	+16	+16	+16	+16	+16	+15	+12.5	+5.5	-2	-7.5

The data shown in Table 8.2 was obtained during an experiment on an active tone control. Plot the frequency response curve using the logarithmic grid shown in Fig.8.35 and use it to determine:

(a) the maximum value of voltage gain (in dB)
(b) the maximum value of voltage gain (expressed as a ratio)
(c) the approximate voltage gain at 50Hz and 30kHz
(d) the two frequencies at which the voltage gain falls to zero
(e) the range of frequencies over which the graph is 'flat' to within -1dB of the maximum
(f) the two frequencies at which the gain has fallen by 6dB from its maximum value.

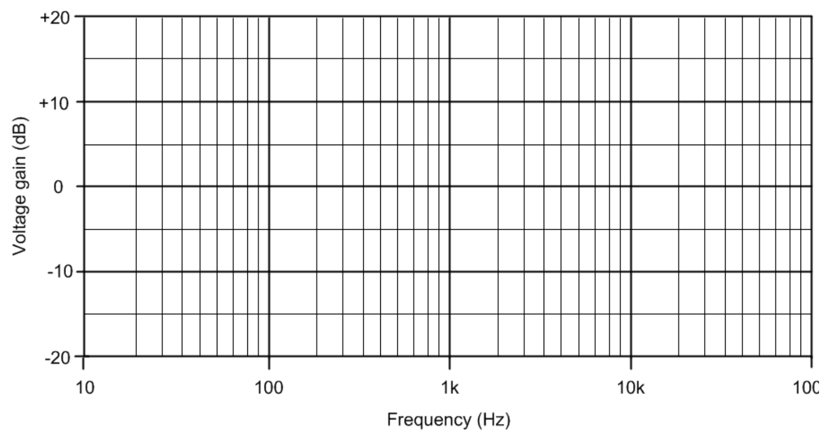


Fig.8.35. See Investigate

Amaze

In most electronic circuits, the signal voltages that we have to deal with range from a few millivolts to a few volts. Similarly, the power levels present in these circuits tend also to be rather modest and usually range from a few milliwatts to a few watts. It's worth considering a few examples where signal voltages and power are either very much smaller or very much larger than this.

This 50-foot dish antenna at the North Kennedy Space Center is supplied with a power of 3kW from a C-band radar to produce an effective radiated power (ERP) of around 3MW!

When you receive a signal on your radio or TV at home, the signal voltage present at the input of the radio or TV receiver is often only a few tens or hundreds of microvolts. Since the impedance of the aerial, coaxial cable and input of the receiver is invariably 75Ω, this suggests that, for a signal of 1 mV, the actual power present at the input of your radio or TV will be in the region of:

$$P_R = \frac{V^2}{Z} = \frac{\left(1\times10^{-3}\right)^2}{75} = \frac{10^{-6}}{75}$$

$$= 0.0133\,\mu\text{W}$$

At the other extreme, consider the power that is delivered to the aerial of a high power transmitting station. This is very much larger. For example, the Crystal Palace TV transmitter currently radiates a power of 1MW (analogue) and 20kW (digital) to reach an estimated viewing population of 11 million people. After 'digital switch over' (DSO) the digital power output will increase tenfold to 200kW.

If it were possible to absorb all of the currently radiated 1MW of analogue power in a single 50 ohm resistor the voltage generated across the ends of the resistor would be given by:

$$V = \sqrt{P\times R} = \sqrt{1\times10^6\times50}$$

$$= 7.07\text{ kV}$$

If the 1MW of radiated power from Crystal Palace isn't quite enough for you, the Boshakova transmitter (used until recently by the *Voice of Russia*) produced a staggering 2.5MW of output, and its output was radiated by no less than eight guyed masts, each around 250 metres tall.

Next month!

In next month's Teach-In we will look at digital-to-analogue and analogue-to-digital conversion.

Anti-aliasing filters

AGUSTÍN TOMÁS posted the following questions about anti-aliasing filters on the *EPE Chat Zone* forum.

I need to design an anti-aliasing filter. After reading a lot on them I found AN699 (Anti-Aliasing, Analog Filters for Data Acquisition Systems) *from Microchip, by Bonnie Baker, which is clear enough except in one point.*

When deciding on the transition band of the filter, given f_S (sampling frequency) she states that $f_{cut\text{-}off}$ of the filter can be made much lower than $f_S/2$. To that, in page 5, she gives this specific example: Assuming a 5th order filter is used in this example:

$f_{CUT\text{-}OFF} = 0.18f_S/2$ for a Butterworth filter

$f_{CUT\text{-}OFF} = 0.11f_S/2$ for a Bessel filter

$f_{CUT\text{-}OFF} = 0.21f_S/2$ for a Chebyshev filter, with 0.5dB ripple in the pass-band

$f_{CUT\text{-}OFF} = 0.26f_S/2$ for a Chebyshev filter, with 1dB ripple in the pass-band

My questions: Isn't it contradictory that the filter has a cut-off frequency much lower than most of the frequencies of interest? Accepted that the above is correct, how does she get those coefficients, which appear as independent of the filter's order?

Up to now they seem drawn from a magic hat... What should I decide first? The order of the filter or cut-off frequency? Sorry, but this is the first time I have faced this subject. Any help is appreciated.

So, this month we will look at anti-aliasing and try to answer these questions, starting with an overview of aliasing. Aliasing is a problem which can potentially occur in any signal processing system which samples the signal. This includes all digital audio and video signal processing. It also includes analogue sampled signal circuits, such as switched capacitor filters. Digital imaging devices such as cameras and scanners can also suffer from aliasing effects (they perform spatial sampling to create the image pixels).

Wagon wheel effect

Aliasing is so called because it causes ambiguities in the sampled data, that is, there could be more than one signal which resulted in the same set of sample values – thus one signal is an alias of the other. Aliasing effects can be observed in everyday life; one often quoted example is the 'wagon wheel effect' where the wheels of a vehicle in a film or video (perhaps a stagecoach in a Western, as the name suggests) appear to be turning at the wrong speed, backwards or even appear stationary. Search the web for 'wagon wheel effect' videos if you would like to see some examples.

A video camera samples the scene in front of it at a certain number of frames per second. If the wheel of a vehicle in the shot rotates an exact number of whole revolutions in the time between frames it will appear to be in the same position in each frame. When the film is viewed, the wheel will appear to be stationary, despite the fact that the vehicle is obviously in motion. However, if the wheel was rotating much more slowly, or if the video frame rate was much higher, we would get a large number of frames per revolution and playback would look as it should. This leads us to the insight that problems will occur if the input (the scene in this case) contains frequencies relatively close to the sampling frequency.

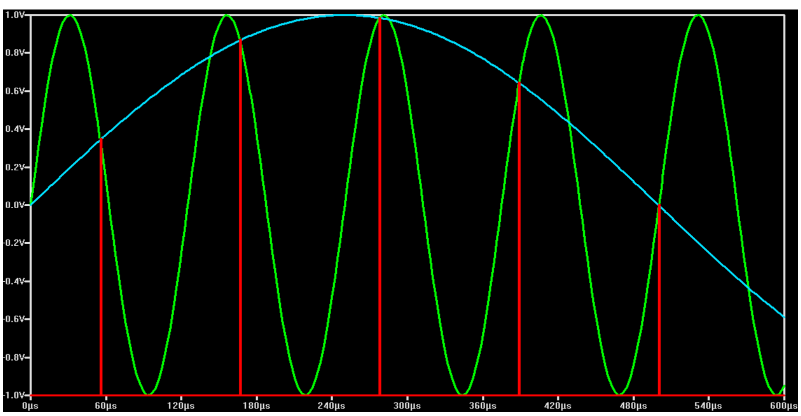


Fig.1. Aliasing of sampled signals. The green and blue waveforms both produce the same set of samples from the red sampling waveform and are therefore indistinguishable after sampling

Waveform sampling

Aliasing of waveform sampling can be seen in Fig.1. Here we have two sinewaves at frequencies of 1kHz and 8kHz, with a sampling process running at 9kHz. The sampling process is indicated by the red pulses in the waveform. The sampling signal obtains the same signal values from both of the sinewaves. Thus, when we only have the sample data (further through the signal processing system, or in a digital recording), we cannot tell if the data was due to a 1kHz or 8kHz sinewave.

Another way to look at this is that if we sampled an 8kHz sinewave at 9kHz, then when the signal was reconstructed (eg, when playing a digital audio recording) we may end up with a 1kHz tone instead of the original 9kHz. The output contains something that was never there in the first place – just like the illusionary stationary or backward-turning wheels on the 'wagon'.

Real audio signals, such as voice and music, are generally much more complex than single sinewaves, but the same aliasing processes can occur during sampling. The resulting output may contain tones which were not in the input, resulting in a loss of fidelity.

The process by which a signal at one frequency in the input 'reappears' at a different frequency in the reconstructed signal is called *folding*, because the effect is like folding the signal's spectrum over to relocate the frequencies.

Nyquist sampling

Mathematical analysis of the process of sampling a signal shows that signals with a frequency of less than half the sampling frequency are reliably represented in the sampled data. This is known as the Nyquist sampling

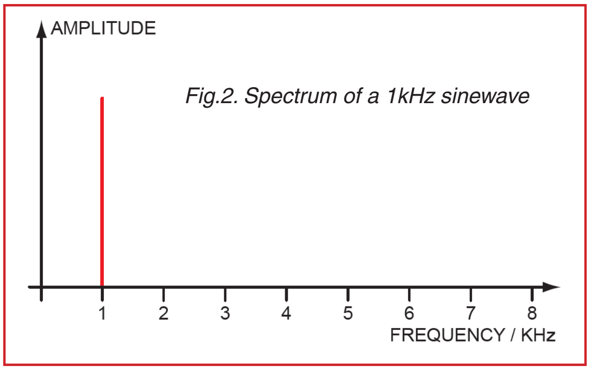


Fig.2. Spectrum of a 1kHz sinewave

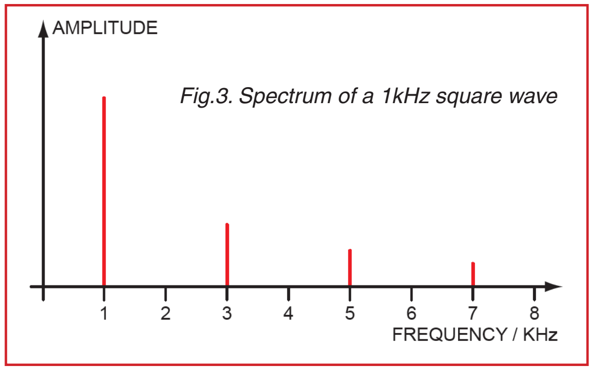


Fig.3. Spectrum of a 1kHz square wave

theorem. The theory shows that if the input does not contain any frequency components beyond half the sampling frequency then it is possible to perfectly reproduce the original signal from the sample data.

A sampling frequency of twice the maximum signal frequency is called the Nyquist frequency or Nyquist rate. Sampling at less than this frequency is called undersampling (which does have its uses). Sampling a rate significantly higher than the Nyquist rate is called oversampling and facilitates low noise, low distortion signal processing.

Anti-aliasing filters

If we remove all frequencies above half the sampling frequency from the input before sampling it, then we will not get any problems with aliasing. This is the job of the anti-aliasing filter. Anti-aliasing filters are not only required in audio and video signal processing; the image sensors in digital cameras are spatially sampling the image projected by the lens onto the sensor. If the image contains small repetitive details, then aliasing can occur. To overcome this, an optical filter is used to provide an amount of blurring which will prevent aliasing.

For electronic signals, the anti-aliasing filter will be a low-pass filter which attenuates frequencies above half the sampling frequency. In order to determine which filtering and sample rate is appropriate, we need to be aware of the set of frequencies present in our signals; that is its *spectrum*. The only waveform for which the spectrum comprises just a single frequency is the sinewave (see Fig.2). Any other periodic waveform can be formed by adding together a set of sinewaves of various frequencies and different amplitudes. For example, a square wave may be described as being at 1kHz, but this is just the fundamental frequency; there are other frequencies present too. This is illustrated in Fig.3, which shows part of the spectrum of a square wave.

If we have a 1kHz sinewave, then sampling at 4kHz will provide sufficient data to reconstruct the sinewave. We would not even have to filter before sampling because the input spectrum does not contain any frequencies about the 2kHz cut-off required to prevent aliasing. However, if we have a 1kHz square wave sampling at 4kHz it will cause aliasing due to the 3kHz, 5kHz, 7kHz, and so on, components of the signal's spectrum.

If we used an anti-aliasing filter with a cut-off of 2kHz with the square wave, we will remove all the spectral components from the square wave apart from the 1kHz fundamental frequency. Thus the spectrum of the signal we actually sampled would be exactly that of a 1kHz sinewave. When we tried to reconstruct the waveform from the sampled data we would get a sinewave not a square wave – probably not what we want. This problem is not a fault of the filtering, nor is it aliasing (the filter prevented that); it is an inappropriate choice of sample rate.

Sample rate

Choice of sample rate and filter cut-off are closely related because usually the filter cut-off will be around half the sample rate. These linked choices are based on an understanding of the spectrum of the signal being sampled, together with a number of other considerations, which we will return to in a moment.

Square waves have a spectrum which in theory extends to infinite frequencies and 'real world' signals may also potentially have very wide spectra; so where do we set the cut-off point? All circuits also produce, or introduce, a certain amount of noise across a wide range of frequencies. Therefore, a more realistic spectrum looks like the one shown in Fig.4.

The general level of noise in the spectrum is referred to as the *noise floor*. Although it is possible to process signals below the noise floor, this is a special requirement, and, in general, it is not worth bothering with frequencies beyond the point where the signal spectrum disappears into the noise floor. So, for the spectrum in Fig.3, we may choose to ignore (and filter out) frequencies above, say, 5kHz, which would imply a sample rate of 10kHz.

In other situations we may know more specifically what range of frequencies we need to deal with. Audio is a case in point, because the requirements are determined by the range of frequencies we can hear. The limit of human hearing is about 20kHz, so it is not necessary to include frequencies above this in or sampled signal, even if they are present and well above the noise floor in the original source. This implies a sampling frequency of around 40kHz.

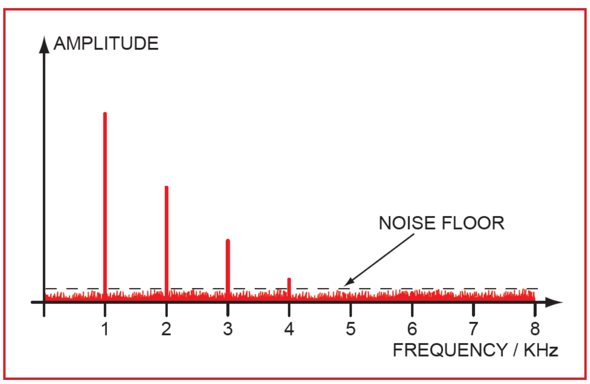


Fig.4. Spectrum of a 'real' signal including noise

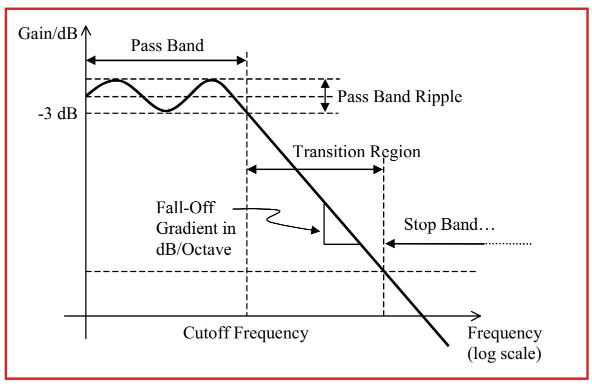


Fig.5. Frequency domain response

The sampling frequency for CD audio is 44.1kHz, which is in line with this.

The other things to bear in mind when selecting sampling frequency is the amount and rate of the data generated. If the data is to be stored, then a high sample rate will require more storage capacity for a given time period. Higher sampling rates will also place more demanding requirements on the signal processing circuits handling the sampled data.

In some cases, reduced quantities of data/bandwidth and/or simpler/cheaper circuits may justify losing part of the original signal and hence the fidelity of the reconstructed signal. For example, for voice telephony, signals limited to around 4kHz and sampled at 8kHz may be sufficient.

Roll-of time

In the discussion so far, we have simply stated that we cut-off the signal frequencies above half the sampling frequency, implying some kind of filter would do this. In practice, it is not possible to have a filter with an infinitely sharp cut-off; this brings us to the issues which Agustín raises – how do we choose the right cut-off frequency?

To pursue this further, we need to consider the response of a real low-pass filter. A general filter response is shown in Fig.5. The specific characteristics of actual filter responses varies with the type of filter, such as the Butterworth, Bessel and Chebyshev types mentioned in Agustín's question.

The vertical axis on filter frequency response graphs shows filter gain or attenuation, it is usually scaled in decibels. The horizontal (frequency) axis of the graph is also usually logarithmic (eg, the scale is marked 1Hz, 10Hz, 100Hz, 1kHz at even intervals). These times-ten steps are referred to as decades.

If the gain (or attenuation) in the pass-band does not vary much with frequency it is described as *flat*. In some filters, the pass-band gain has distinctive ripples as frequency varies; the depth of these ripples is usually measured in decibels. The stop-band may also have ripples. Pass-band ripples are mentioned in a couple of the filter specifications quoted by Agustín.

The slope of the frequency response in the transition region, and possibly the stop-band, indicates how quickly the filter's gain drops as the frequency moves away from the cut-off frequency. The slope is measured in dB per-octave, or dB per-decade, this value is called the *fall-off* or *roll-off*. The fall-off may be different near and far from the cut-off, thus we can describe both initial fall-off and ultimate fall-off.

If we have a sampling system in which the sampling rate is exactly equal to twice the highest required input frequency, as Nyquist theory indicates we can do, then using a real filter for aliasing will lead to problems. If we make the cut-off frequency equal to half the sample rate, then frequencies in filter's transition band may still have significant amplitude at the filter's output and will cause aliasing.

If we try to avoid the aliasing by shifting the filter's cut-off to a lower frequency we may significantly attenuate some of the required frequencies. The solution is to increase the sampling rate above twice the maximum required frequency so there is some leeway for the filter's transition. Thus, for example, high-quality audio sampling rates ideally need to be more than twice the maximum audio frequency of 20kHz (as is the case with CD audio).

Using a higher order anti-aliasing filter reduces the amount of leeway required and allows us to use a sampling frequency closer to the Nyquist rate. However, higher order filters are generally more difficult to design and often have very stringent requirements on component accuracy and performance.

Trade-off

There is trade-off between sample rate, filter order, filter cut-off, signal quality and circuit cost and complexity. So there is no simple answer to Agustín's question about what to choose first – it will depend on the constraints and requirements of a particular design. If the sample rate is constrained to be close to the Nyquist rate, this may force the use of a higher order filter. If cost is an issue, a lower order filter may be considered, as long as a higher sample rate can be used to avoid aliasing in the transition region. However, if the higher sampling rate also increases cost (eg, if a better analogue-to-digital converter (ADC) is needed), then a higher order filter may still be a more effective choice.

We can be a bit more specific about the requirements of the filter if we consider the signal quality we require. This brings us to Agustín's question about the cut-off frequencies stated in the Microchip application note. In a similar augment to the one made earlier about not (usually) trying to sample signal frequencies below the noise floor, we can relate the filter requirements to the noise performance of the sampling system.

When using an ADC to convert the signal samples to digital data there is an error inherent in turning a continuous analogue signal into a set of discrete values. This is known as *quantisation error*. For example, with an 8-bit converter there are 256 possible output values – a signal with a 1V range will be converted in steps of about 3.9mV. Thus, each conversion may be subject to an error of up to ±3.9/2 = ±1.95mV.

Quantisation error manifests as noise in the sampled signal. The signal-to-noise ratio (SNR) due to quantisation error in this case is 20log(1/0.0039) = 20log(256) = 48dB. This is a simplification, because we are assuming that all sample points occur with equally likelihood,

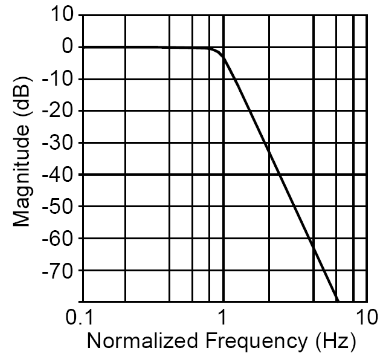


Fig.6. A 5th Order Butterworth frequency response graph from Microchip application note AN699 [Bonnie Baker]

which may not be true for real signals. However, in general, for a uniform signal and an N-bit converter we can find the quantisation error as follows:

$$SNR_{Quantisation} = 20\log(2^N)$$

The anti-aliasing filter does not need to attenuate the signal at half the sampling frequency by more than the signal-to-noise ratio of the data converter. In the example in the Microchip application note that Agustín refers to, a 12-bit converter is used. The above formula gives the SNR as 72dB. However, if a sinewave is assumed, the sample values do not occur evenly and an SNR of 74dB is more accurate (this is the figure used in the application note).

To obtain the required cut-off frequency we have to find the relative frequency between the pass-band (cut-off) and the point at which the filter provides attenuation equal to the quantisation SNR. This will depend on the filter characteristic, so will be different for each type of filter.

Figure 6 shows the characteristic of one of the filters (5th order Butterworth) discussed in the application note. From the graph (although we cannot read it very accurately), we find the -74dB frequency is at approximately $5.5f_c$, where f_c is the cut-off frequency. This means that the cut-off frequency has to be at $(1/5.5)f_s/2 = 0.18f_s$. Where $f_s/2$ is half the sampling frequency f_s. This is the result quoted by Agustín in his question for the Butterworth filter.

The cut-off frequency of $0.18f_s$. is quite a bit lower than $f_s/2$, but this is necessary to avoid aliasing causing significant disruption of the sampled signal, given the capabilities of the filter used. However, the filter cut-off (at $0.18f_s$) should not be significantly lower than frequencies of interest. If this is the case it will be necessary to increase the sample rate or use a higher performance (faster cut-off) anti-aliasing filer.

Reference

Bonnie C. Baker, *Anti-Aliasing, Analog Filters for Data Acquisition Systems*, Microchip Technology Inc. Application Note AN699, 1999. **http://ww1.microchip.com/downloads/en/AppNotes/00699b.pdf**

Our periodic column for PIC programming enlightenment

PIC Internet Computer – Part 6

IN the previous *PIC n' Mix* article (April '11) we installed the Microchip Application library, and did a test build of the example project on which we will base our PIC software development. This month, we start the process of trimming the Microchip source code down to a manageable set of files to enable us to understand what source code is being used, and why.

The Microchip Application library is huge – over 6000 files and 400 example projects. Buried in this lot are the few dozen files required to provide a TCP/IP stack and SD-Media file system; our task over the last two months has been to find them and produce a much simpler build environment.

This has been a much harder task than originally expected. The example project that best suits our needs, 'TCPIP MDD SD Card Demo App-C30', is designed for a different processor in the PIC family, and is tailored to the Explorer 16 hardware platform. This uses a large PIC24FJ processor with many hardware features, all used by the example project, and consequently there is a lot of code to 'unwrap' to get back to the bare essentials. Fortunately, the underlying stack and file system code have been created in a portable fashion, and so once the example project files were paired back, getting a working system was a quick task.

If this sounds a little scary, fear not – we have done all this work so you don't have to, and the reduced file set is available in a zip file on the *EPE* website against this month's article. It was an interesting process, so we will go through it this month.

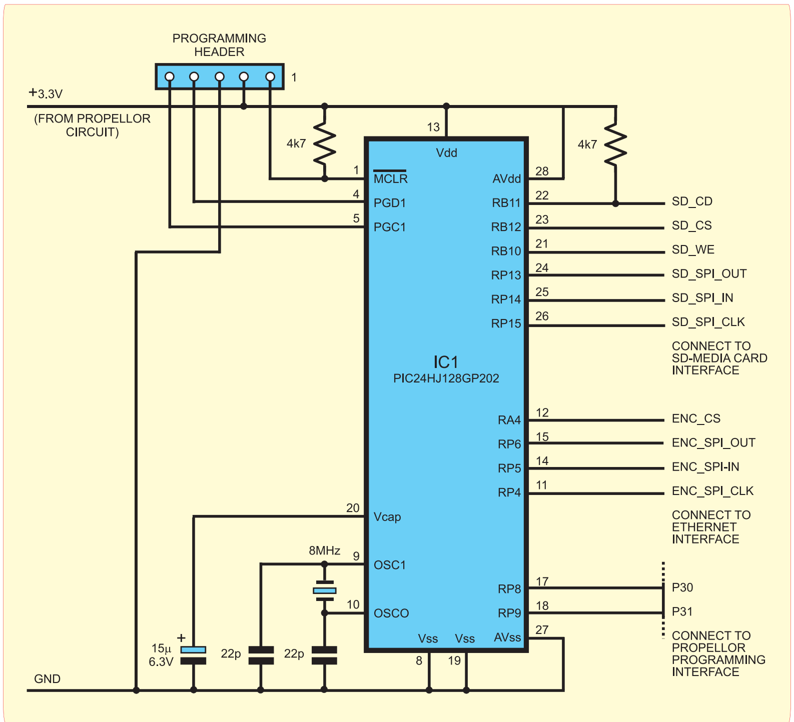


Fig.1. Circuit diagram for the PIC24 processor interfaces

Processor interface

Last month, we built the example project, 'TCPIP MDD SD Card Demo App-C30.mcw', in the 'TCPIP MDD Demo App' sub-directory. There are only three files that interest us in this directory: **MainDemo.c** that 'glues' the code into a useful application, **TCPIPConfig.h** that defines what features of the TCPIP stack code we wish to use, and **HardwareProfile.h** that defines what your hardware consists of, and what port pins connect to what software features. This last file is the one we need to modify the most, as our hardware is completely different to the Explorer 16 hardware platform.

So, now we need to look at what our hardware connections are going to be. We already know that we will be using the 28-pin PIC24HJ processor; Fig.1 now introduces the connections to the Ethernet and SD-Media interfaces. We will describe those circuits later, but we have to define the interfaces now so that we can change the software to match. The tricky part will be creating the reduced file set – getting it to run on our hardware will be easy!

Back to the software

We have already mentioned that this example project uses a different processor and hardware setup, but before we start even selecting the correct processor, let's strip away as much as possible of the unused code. If you are following along literally, don't worry if you make a mistake at this point; you can always re-install the application libraries. For simplicity, we made a directory copy before starting, and it proved invaluable when reversing over-ambitious code pruning. More than once!

When you open the **.mcw** project file in MPLAB, the project window shows the various source directories in use, and it was a simple job of deleting the apparently unused directories one at a time, followed by a clean re-build of the code to confirm that the code still builds. After just five minutes the number of files in the application library reduced from 6287 to approximately 400. Still some way to go, but we will improve on that once we have set up the initial basic build.

The project is configured to run on the PIC24FJ128GA010 processor, which is a large 100-pin device with lots of I/O. The processor we are using, the PIC24HJ128GP202, is physically a much smaller device – so we can solder it – which means that we will have to remove from the demo application many of the I/O features that are included in it, and get to a basic configuration of the SD card interface and TCP/IP stack.

This turned out to be *the* major task, but resulted in a **Maindemo.c** file significantly smaller than at the start. The other **.c** source files in the 'TCPIP MDD Demo App' directory are now no longer used, but we will leave them there for now, as they may provide a useful reference for how to use the stack features in our own application. For now, we are building a system that consists of nothing more than the Stack and SD Media interface, plus the ability to respond to network 'Pings' (as otherwise we would not be able to confirm the code actually works!)

It took several evenings of patient experimenting to decouple the unused features and files from the project and slowly reduce the content of the main demo source

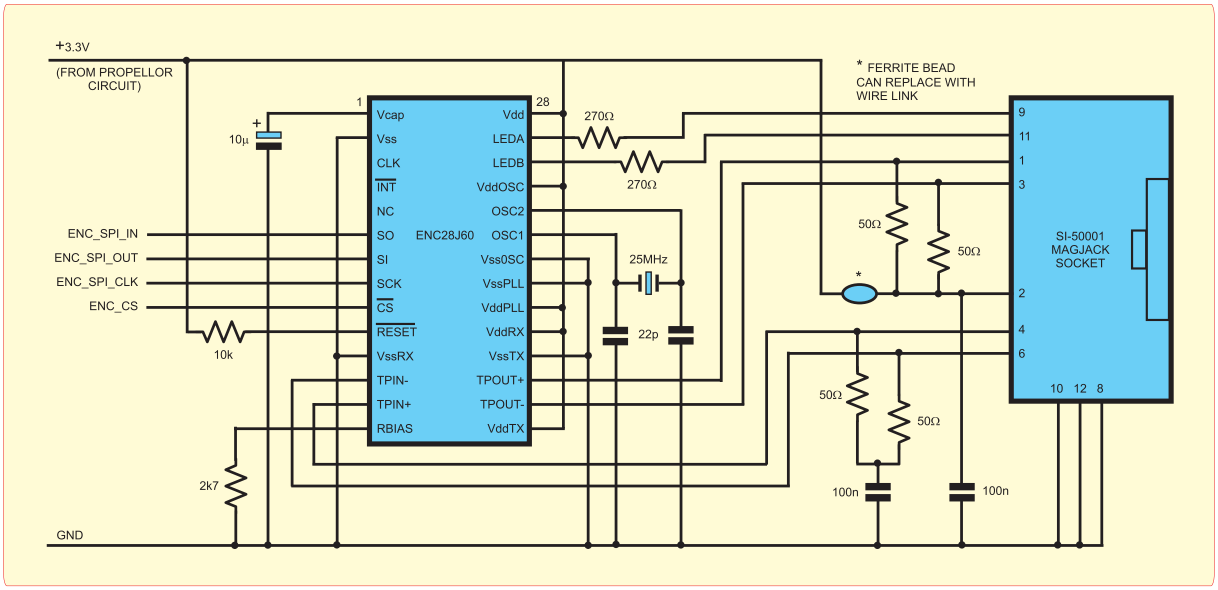


Fig. 2. Ethernet Interface

until only a manageable amount of source code remained. The code utilisation, still targeted to the original processor, fell from 132K down to 73K bytes. A good start, but there is still room for further optimisation.

We will continue with removing the detritus later; now it's time to change the project to our processor, and sort out the issues that arise from that. Typically, this involves removing code associated with hardware peripherals our chip does not have, and providing the hardware initialisation to match our circuits need.

As expected, the change of processor generated several error messages, all pointing to the definition of functions associated with I/O ports not present on our 28-pin device. All that was left to do was add the initialisation code that is specific to the PIC24HJ which we copied for an earlier *PIC n' Mix* process (the one on PIC24 video generation.)

The code built, with no errors or significant warnings reported (the code is available for download from the *EPE* website). Oh, if only we had some Ethernet hardware to connect it to!

That part, fortunately, is the trivial part. We are going to completely re-use the hardware design from an earlier *PIC n' Mix* article on embedded Ethernet. The circuit diagram and associated connections to the PIC24HJ processor are shown in Fig.2, with the Ethernet socket details shown in Fig.3 and Fig.4.

I wired up the ethernet circuit (which we had kept on it's own small stripboard) and connected it to a router, and five minutes later the PC was happy 'pinging' it.

Circuit layout

You may be wondering why we have used up three of our precious I/O pins on the processor duplicating the SPI bus interface. As you may be aware, the SPI bus is intended to support multiple devices, individually accessed by a unique chip select pin per device. We have used two to minimise the changes required to the code on which this project is based, as that had the Ethernet and SD-Media interfaces on two separate peripherals. We can move to a single, shared SPI interface once the two interfaces have been proven to work.

As with all engineering activities, try to take small steps, and deal with each issue one at a time, verifying things still work before moving on. In our project, reading and writing to files is not a 'real time'

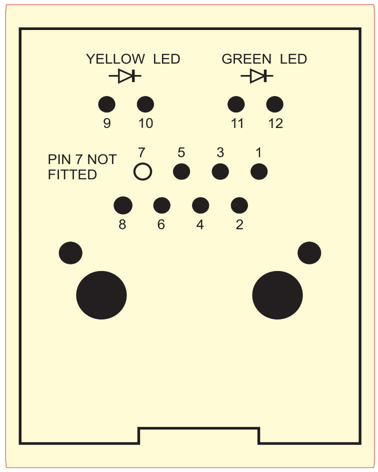


Fig. 4. SI-50001 connector, viewed from above

activity, so it will not cause a problem if we share a single SPI interface between the Ethernet IC and the SD Media card.

In the next article, we will hook these two boards up to the Propeller circuit and start talking to the Internet.

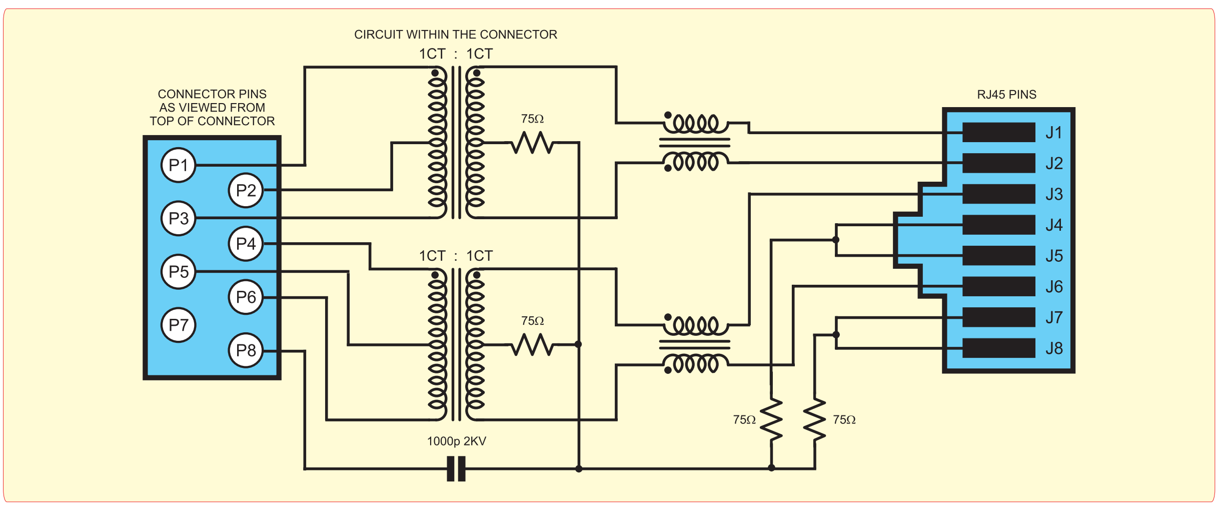


Fig. 3. Ethernet socket internals

By Robert Penfold

INTERFACE

Back to BASICs

FOR some years now, the software featured in *Interface* articles has been written using the latest version of Visual BASIC, or more recently, the latest version of Visual BASIC Express Edition. The latter being available as a free download from the Microsoft website.

One reason for using Visual BASIC is that it is the most popular PC programming language, both in the UK and on a worldwide basis. The fact that the Express version is available as a free download also helps to make Visual BASIC a good choice. However, as readers point out from time to time, there are alternatives.

It has to be admitted that Visual BASIC is far from universally popular in its current guise. It is more a development of Visual C than a descendant of the original Visual BASIC language. Being fluent in a traditional BASIC language such as GW or BBC BASIC is likely to be more of a hindrance than a help when using Visual BASIC.

It is perhaps a little less visual than was once the case, and the programming language itself is so complex that the 'BASIC' part of the name has become ironic! It is still possible to produce short but highly effective programs using Visual BASIC, but finding the few lines of code that will do the job can be very arduous.

GW BASIC is now in the realms of 'abandon ware', which simply means that the owner of the copyright in the software does not bother to enforce it any more. Any good search engine should find a few sources where a free copy of GW BASIC can be downloaded.

It will run quite happily in a DOS window under a modern version of Windows, such as 7 or Vista (Fig.1), but it is likely to be of limited value on a modern PC. It will run in a non-resizable window just 640 pixels wide, which is likely to be quite small on a modern high-resolution screen.

Although GW BASIC has Inp and Out commands that make it easy to directly control hardware on the microprocessor's busses, a modern PC does not have expansion slots that provide access to these buses. Neither does it have serial or parallel ports that can be accessed via these commands. A modern version of Windows would almost certainly block this type of direct access anyway.

It has facilities for dealing with COM (serial) ports, but these are primarily intended for using the COM ports with disc files. In theory, it would be possible to use these facilities for interfacing to user add-ons via a virtual COM port on a USB port, but it is doubtful if it would be worth the effort involved.

GW BASIC was replaced by a slightly improved version called QBASIC, which is an interpreted version of the Quick BASIC compiler. Like GW BASIC, these two languages could theoretically be used with devices connected to a virtual COM port. Also, as with GW BASIC, it would probably not be worthwhile using this method.

Small BASIC

Microsoft received a fair amount of criticism for developing Visual BASIC into something that was a long way from the original concept of a BASIC programming language. They responded with a little known alternative called Microsoft Small BASIC (Fig.2), which is available as a free download from the Microsoft website at: **http://www.microsoft.com/downloads/en/details.aspx?FamilyID=b006d58d-c2c7-44ad-936b-e7e2d7de793e**.

This is a BASIC interpreter that lives up to its name by implementing an extremely basic version of the BASIC programming language. It is not really intended as a means of producing proper application programs, and is designed more as an easy-to-learn programming language for beginners. It has potential as a simple way of experimenting with and learning about PC interfacing. There is no built-in serial port communication, but it can be added via an extension that is also available from the Microsoft website at: **http://archive.msdn.microsoft.com/sbserial/Release/ProjectReleases.aspx?ReleaseId=2466**.

With the supplied DLL and XML files added to the appropriate folder, I found that the new serial port extension was recognised by Small BASIC, but that the new instructions were not. No doubt, this could be cured by a bit of delving into the way in which Small BASIC handles extensions, and it should then be ideal for educational use or for experimenting with PC interfacing. However, something a little more sophisticated might be needed for producing the final application software for home constructed PC add-ons.

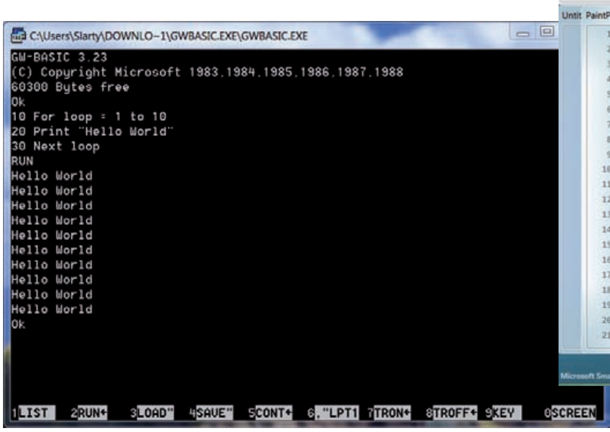


Fig.1. GW BASIC will run under a modern version of Windows in a DOS box, but it could be difficult to get it to do anything useful in a modern interfacing context

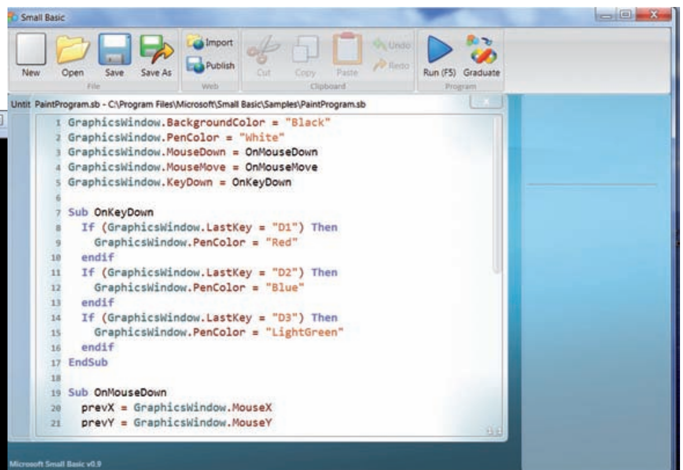


Fig.2. MS Small BASIC is a very simple language that is good for learning to program and experimenting. However, it is probably too basic for producing practical applications

Golden oldie

So, are there any truly viable alternatives for those who would prefer something that is closer to a traditional BASIC and lacks the complexities of a modern version of Visual BASIC? There are certainly plenty of alternatives to Visual BASIC currently available, but they are not necessarily suitable if you need to interface your PC to home produced add-ons. It is still possible to run Microsoft's GW BASIC on a modern PC, but as always with these things, it is not as simple as that.

Just BASIC

A programming language called Liberty BASIC has been mentioned in *Interface* articles from time-to-time, and this is a popular choice for those requiring a traditional BASIC that will work well with modern versions of Windows. Liberty BASIC is not free, but at 59.95 US dollars it is not expensive, and there is often a discount on offer.

There is a free version called Just BASIC (Fig.3), and this is essentially the same as Liberty BASIC, but with a few simplifications. The main one is it lacks the compile facility of Liberty BASIC.

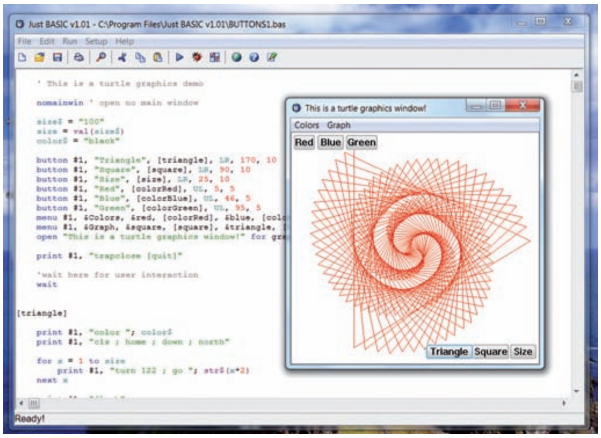


Fig.3. Just BASIC has a conventional Windows style user interface, with loaded programs being run in a separate window. It has good interfacing potential, and is based on quite a powerful version of BASIC

It is effectively an interpreted version of Liberty BASIC, with a few further simplifications. It is possible to write, load and save programs, but they can only be run from within Just BASIC. Just BASIC can produce and run tokenised programs, which load faster than the normal BAS files and can be distributed as royalty-free programs with Just BASIC's runtime engine.

This will probably be adequate for most users, but Liberty BASIC will be needed in order to compile true standalone programs. Note though, that even with Liberty BASIC it is not possible to compile standalone EXE files. The compiled programs still require some support files.

Liberty BASIC and Just BASIC have good potential for use with homemade PC add-ons. The serial ports, whether virtual or otherwise, can be set up using a special version of the OPEN instruction. In its standard version this is used to open files or new windows, and data is written to any open device using the PRINT command.

Data can, therefore, be written to a serial port in more or less the same way that data is printed on the screen in most versions of BASIC. It is just a matter of using a PRINT instruction to send a variable or text string to the appropriate device.

A specified number of bytes can be read from an open serial port using the INPUT$() function, which is similar to reading the keyboard using a conventional BASIC language. There is a function to check the number of bytes available to be read, and this should be used to provide a hold-off until an adequate number of bytes is available.

As is usually the case when reading from a serial port, the data is in string form and not in numeric form. Therefore, the sending device has to provide numeric data in a coded form, such as hexadecimal numbers converted into pairs of strings characters, or the received ASCII characters have to be converted into their code numbers. Just BASIC has the usual BASIC CHR$ and ASC$ functions, and converting between ASCII characters and ASCII values, or vice versa, should not present any problems.

Just BASIC offers a good choice for those requiring a relatively easygoing programming language that can be used with USB ports via virtual COM ports. It has the ease of use associated with traditional BASIC languages, but it will work quite happily on a modern PC running under Windows 7 or Vista. It should work with any COM port that is installed properly in Windows. The Just BASIC download is just 2.4 megabytes, so it is not necessary to have a broadband connection in order to download and try it.

Old favourite

Readers who have been with *EPE* since it was just plain *EE* might remember the Beeb Micro articles, which eventually became the *Interface* articles with the demise of the BBC Model B computer. Although the computers that have BBC BASIC built-in are long obsolete and now collectable items, BBC BASIC lives on. A version for Windows written by R T Russell is available for £29.95 including VAT, and a simplified version is available as a free download (Fig.4).

The free version cannot compile standalone programs, and the amount of memory available for the user's program, data and stack is restricted to 8 kilobytes. The free version can be downloaded at:

http://www.bbcbasic.co.uk/bbcwin/download.html

The Windows version of BBC BASIC has facilities for using serial ports, and as with Liberty/Just BASIC, it should work with any serial port that is correctly installed in Windows. It will run under any version of Windows from 95 through to Windows 7. The serial ports are treated in a similar fashion to files, and an OPENUP instruction is used to initiate a port.

Data can be written to a file using the PRINT# and BPUT# instructions. BPUT# seems to be the one to use if it is only necessary to write single bytes of numeric data, and it can also be used for strings. PRINT# can also be used for numeric and string data, but only in a standardised form. For most interfacing applications it is BPUT# that represents the better choice.

When reading data, there is an EXT# function that returns the number of bytes in the received data buffer. The BGET#, IN-

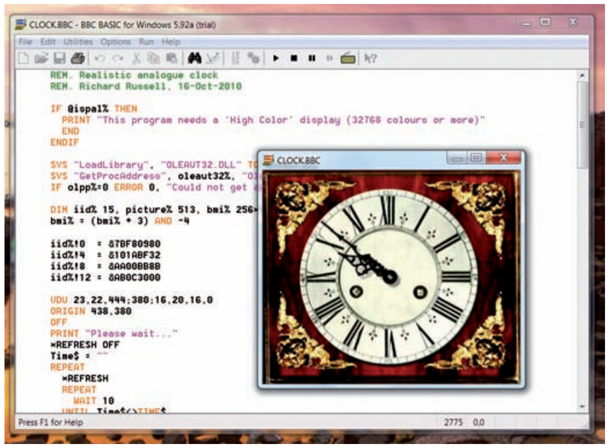


Fig.4. Like Just BASIC, BBC BASIC for Windows has a conventional user interface and runs loaded programs in a separate window. It also has instructions that permit the serial ports to be accessed

PUT# and GET$# instructions can be used to actually read the data, and these will wait until a suitable number of bytes have been received before completing and moving on to the next instruction. Checking for a suitable number of buffered bytes of data before reading a port ensures that the program cannot simply hang indefinitely while it waits for data that is never received.

BGET# operates with single bytes of data, which makes it the best option for simple interfacing. The other two handle multiple bytes, and are better when using strings of characters to communicate with add-on devices.

BBC BASIC for Windows appears to be a good choice when writing software for use with user add-ons interfaced to a serial port or USB virtual serial port. It provides easy communications with any serial port that Windows recognises, and it will work with old or new computers using old or new versions of Windows. If you are familiar with the original BBC BASIC you will find some old favourites such as Repeat…Until loops and Mode 7 with its Teletext graphics.

The rest

Any good search engine should provide details of many other versions of BASIC for use on PCs. Unfortunately, most of these seem to be very old, and are of no more practical value than GW BASIC or QBASIC. Others are rather specialised in nature and are only intended for (say) games programming. There is a programming language called SmallBASIC which is part of the GNU Project, and as such it is free and reasonably up-to-date. Unfortunately, at present the documentation for this software is rather sparse, but as far as I have been able to ascertain it does not currently have any built-in provision for using serial ports.

BBC BASIC and Liberty/Just BASIC are up-to-date, well documented, and can use the serial ports. The free versions should at least get you started, and could be all that you will need. This would seem to make them the best alternatives to Visual BASIC when producing the software for home constructed add-ons.

Max's Cool Beans

By Max The Magnificent

Hot topic

Recently, I ran across a really interesting Radiation Dose Chart on the xkcd.com website (**http://xkcd.com/radiation**). This is a really clever site – the cartoons are often extremely thought-provoking, and every now and again they will come up with something like this chart that really makes you think.

First, it made me think how clever they are to compress so much data into so small a space in such a way as to be so understandable. Second, it made me think it might be a good idea to invest in a Geiger counter. Also called a 'Geiger-Müller counter', a Geiger counter is a type of particle detector that measures ionizing radiation. Being a bit of a 'worry-wart,' every now and again I get feelings of grim forebodings (these feelings usually come after watching one of those television programs with a title like 'Ten ways in which the world could end by Wednesday lunchtime.')

The point is, I live only about 15 miles from the Browns Ferry nuclear plant (**www.tva.gov/power/nuclear/brownsferry.htm**), which is managed by the Tennessee Valley Authority. I did a search for 'Geiger counter' on **Amazon.com**, but reasonably good ones cost anywhere from $350 to $500, which is too rich for my blood. I did see a Ghost Meter on Amazon that was very reasonably priced at only $29.99, but since I don't believe in Ghosts – and since it doesn't double up as a Geiger counter – I decided to pass.

Well, my chum Brian pointed me at the Kits USA website (**www.kitsusa.net**), where they have all sorts of educational do-it-yourself kits, including a bunch of Geiger Counters. I was immediately attracted to the C-6979 Sensitive Geiger Counter Kit (on the basis that this was the cheapest [grin]). According to the website, this uses a Russian Geiger-Muller tube and is sensitive to beta and gamma rays.

Fortunately, 'I know which end of the soldering iron is the hot one', so I immediately placed an order. I have to say that – generally speaking – the instructions that came with the kit are first rate. Even a complete dingbat like myself should have no trouble assembling one of these. Thus, I shortly had the assembled kit sitting on my desk. So, with great excitement I connected the battery, turned the power switch to its ON position, the LED lit up, the speaker clicked once, and … nothing else happened.

'Oh dear,' I thought to myself (or words to that effect). The thing was that I didn't have a radiation source to hand. I remember the good old days when wristwatches had 'glow-in-the-dark' numbers based on the use of highly radioactive radium, but my current wristwatch does not boast this feature.

So I went for a wander round the building in which my office is located to see if anyone had a glow-in-the-dark watch. Perhaps, not surprisingly, the first person I asked responded by saying 'Why do you want one?' When I explained, he told me that a few minutes before he had seen Bruce (the guy who owns the company that owns the building) wandering around carrying a puck of radioactive material.

So I hunted Bruce down, and sure enough he had a puck of radioactive cesium that emits beta and gamma radiation in his pocket. Why? I didn't ask. As the years have gone by I've found it makes my life a lot simpler if I don't inquire too deeply about this sort of thing. So I borrowed Bruce's puck and held it next to my Geiger counter… still nothing.

When I reported back to Bruce, he did point out that his puck was only mildly radioactive at 5 micro-sieverts, which really isn't much in the scheme of things (see the Radiation Dose Chart I mentioned earlier). So is this enough to trigger my counter? Who knows?

The instructions that came with the kit do include some trouble-shooting instructions. They start with 'Check that you've connected the battery,' type directions, but build up to more useful things like 'Use a wire to briefly connect the two sides of the GM tube and you should hear a click.' When I do this I do indeed hear a click (hurray) and the LED dims a little, so I think this sort of indicates that things are working.

Then I remembered the Browns Ferry nuclear plant, so I sent an email to the TVA pointing out that we were actually a match made in heaven – here I am with a Geiger counter, but with no radioactive source with which to test and calibrate it – and there they are with a great big nuclear power plant with nothing better to do than generate a lot of electricity. I mentioned that I would be happy to drive over and use my Geiger counter to make sure that everything was as it should be at their end. Sad to relate, I haven't heard back from them thus far!

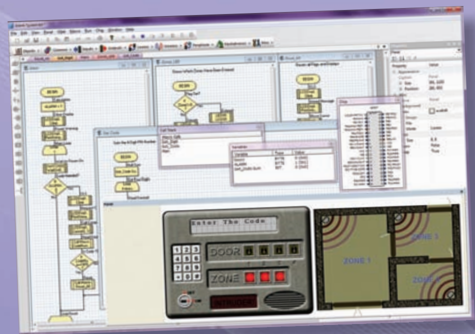
Check out 'The Cool Beans Blog' at www.epemag.com

Catch up with Max and his up-to-date topical discussions

EPE IS PLEASED TO BE ABLE TO OFFER YOU THESE

ELECTRONICS CD-ROMS

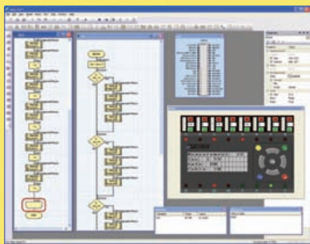
FLOWCODE 4®
NO CODING, NO LIMITS...



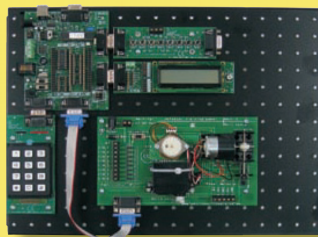
Flowcode 4 is one of the World's most advanced graphical programming languages for microcontrollers. The great advantage of Flowcode is that it allows those with little experience to create complex electronic systems in minutes.

Flowcode's graphical development interface allows engineers to construct a complete electronic system on-screen, develop a program based on standard flow charts, simulate the system and then produce hex code for PICmicro® microcontrollers, AVR microcontrollers, ARM microcontrollers, dsPIC and PIC24 microcontrollers.

Design
Flowcode contains standard flow chart icons and electronic components that allow to you to create a virtual electronic system on screen. Drag icons and components onto the screen to create a program, then click on them to set properties and actions.



Simulate
Once your system is designed you can use Flowcode to simulate it in action. Design your system on screen, test the system's functionality by clicking on switches or altering sensor or input values, and see how your program reacts to the changes in the electronic system.



Download
When you are happy with your design click one button to send the program directly to your microcontroller based target. Targets include a wide range of microcontroller programmers, upstream E-blocks boards, the Formula Flowcode robot, the MIAC industrial controller, or your own system based on ECIO technology.

FlowKit
The FlowKit can be connected to hardware systems to provide a real time debug facility where it is possible to step through the Flowcode program on the PC and step through the program in the hardware at the same time. The FlowKit can be connected to your own hardware to provide In-Circuit Debug to your finished designs.

PRICES

Prices for each of the CD-ROMs above are: ***(Order form on third page)***

(UK and EU customers add VAT to 'plus VAT' prices)

Hobbyist/Student	**£45.95**	**inc VAT**
Professional (Schools/HE/FE/Industry)	**£149**	**plus VAT**
Professional and Flowkit bundle	**£175**	**plus VAT**

PICmicro TUTORIALS AND PROGRAMMING

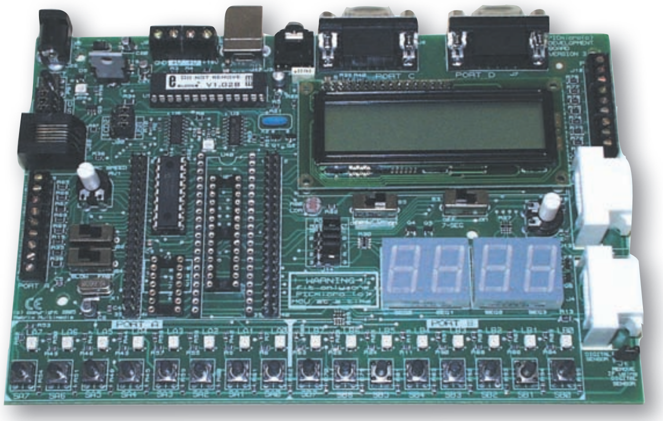
HARDWARE

VERSION 3 PICmicro MCU development board

Suitable for use with the three software packages listed below.

This flexible development board allows students to learn both how to program PICmicro microcontrollers as well as program a range of 8, 18, 28 and 40-pin devices from the 12, 16 and 18 series PICmicro ranges. For experienced programmers all programming software is included in the PPP utility that comes with the development board. For those who want to learn, choose one or all of the packages below to use with the Development Board.

- Makes it easier to develop PICmicro projects
- Supports low cost Flash-programmable PICmicro devices
- Fully featured integrated displays – 16 individual LEDs, quad 7-segment display and alphanumeric LCD display
- Supports PICmicro microcontrollers with A/D converters
- Fully protected expansion bus for project work
- USB programmable
- Can be powered by USB (no power supply required)



£161 including VAT and postage, supplied with USB cable and programming software

SOFTWARE

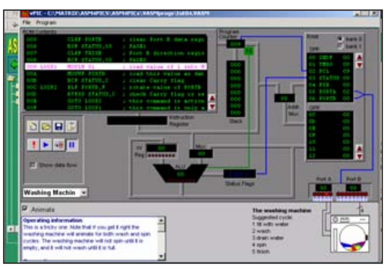
ASSEMBLY FOR PICmicro V3

(Formerly PICtutor)

Assembly for PICmicro microcontrollers V3.0 (previously known as PICtutor) by John Becker contains a complete course in programming the PIC16F84 PICmicro microcontroller from Arizona Microchip. It starts with fundamental concepts and extends up to complex programs including watchdog timers, interrupts and sleep modes.

The CD makes use of the latest simulation techniques which provide a superb tool for learning: the Virtual PICmicro microcontroller, this is a simulation tool that allows users to write and execute MPASM assembler code for the PIC16F84 microcontroller on-screen. Using this you can actually see what happens inside the PICmicro MCU as each instruction is executed, which enhances understanding.

● Comprehensive instruction through 45 tutorial sections ● Includes Vlab, a Virtual PICmicro microcontroller: a fully functioning simulator ● Tests, exercises and projects covering a wide range of PICmicro MCU applications ● Includes MPLAB assembler ● Visual representation of a PICmicro showing architecture and functions ● Expert system for code entry helps first time users ● Shows data flow and fetch execute cycle and has challenges (washing machine, lift, crossroads etc.) ● Imports MPASM files.

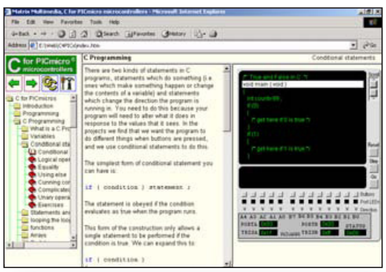


'C' FOR 16 Series PICmicro Version 4

The C for PICmicro microcontrollers CD-ROM is designed for students and professionals who need to learn how to program embedded microcontrollers in C. The CD-ROM contains a course as well as all the software tools needed to create Hex code for a wide range of PICmicro devices – including a full C compiler for a wide range of PICmicro devices.

Although the course focuses on the use of the PICmicro microcontrollers, this CD-ROM will provide a good grounding in C programming for any microcontroller.

● Complete course in C as well as C programming for PICmicro microcontrollers ● Highly interactive course ● Virtual C PICmicro improves understanding ● Includes a C compiler for a wide range of PICmicro devices ● Includes full Integrated Development Environment ● Includes MPLAB software ● Compatible with most PICmicro programmers ● Includes a compiler for all the PICmicro devices.



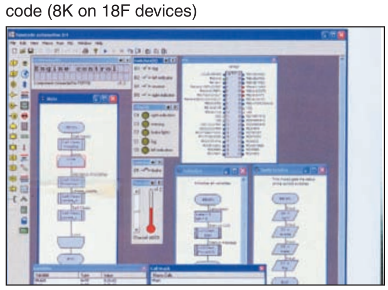
Minimum system requirements for these items: Pentium PC running, 2000, ME, XP; CD-ROM drive; 64MB RAM; 10MB hard disk space.
Flowcode will run on XP or later operating systems

FLOWCODE FOR PICmicro V4

Flowcode is a very high level language programming system based on flowcharts. Flowcode allows you to design and simulate complex systems in a matter of minutes. A powerful language that uses macros to facilitate the control of devices like 7-segment displays, motor controllers and LCDs. The use of macros allows you to control these devices without getting bogged down in understanding the programming. When used in conjunction with the Version 3 development board this provides a seamless solution that allows you to program chips in minutes.

- Requires no programming experience
- Allows complex PICmicro applications to be designed quickly
- Uses international standard flow chart symbols
- Full on-screen simulation allows debugging and speeds up the development process.
- Facilitates learning via a full suite of demonstration tutorials
- Produces ASM code for a range of 18, 28 and 40-pin devices
- 16-bit arithmetic strings and string manipulation
- Pulse width modulation
- I2C.

New features of Version 4 include panel creator, in circuit debug, virtual networks, C code customisation, floating point and new components. The Hobbyist/Student version is limited to 4K of code (8K on 18F devices)



PRICES

Prices for each of the CD-ROMs above are:

(Order form on next page)

(UK and EU customers add VAT to 'plus VAT' prices)

Hobbyist/Student	£45.95	inc VAT
Professional (Schools/HE/FE/Industry)	£99	plus VAT
Professional 10 user (Network Licence)	£350	plus VAT
Site Licence	£699	plus VAT
Flowcode Professional (Schools/HE/FE/Industry)	£149	plus VAT
Flowcode 10 user (Network Licence)	£399	plus VAT
Flowcode Site Licence	£799	plus VAT

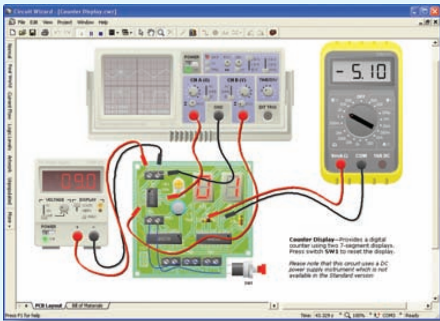
CIRCUIT WIZARD

Circuit Wizard is a revolutionary new software system that combines circuit design, PCB design, simulation and CAD/CAM manufacture in one complete package.

Two versions are available, Standard or Professional.

By integrating the entire design process, Circuit Wizard provides you with all the tools necessary to produce an electronics project from start to finish – even including on-screen testing of the PCB prior to construction!

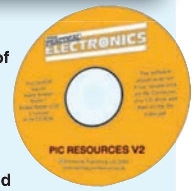
- *Circuit diagram design with component library (500 components Standard, 1500 components Professional)*
- *Virtual instruments (4 Standard, 7 Professional)*
- *On-screen animation*
- *Interactive circuit diagram simulation*
- *True analogue/digital simulation*
- *Simulation of component destruction*
- *PCB Layout*
- *Interactive PCB layout simulation*
- *Automatic PCB routing*
- *Gerber export*
- *Multi-level zoom (25% to 1000%)*
- *Multiple undo and redo*
- *Copy and paste to other software*
- *Multiple document support*



This is the software used in our *Teach-In 2011* series.
Standard **£61.25** inc. VAT
Professional **£91.90** inc. VAT

Minimum system requirements for these CD-ROMs: Pentium PC, CD-ROM drive, 32MB RAM, 10MB hard disk space. Windows 2000/ME/XP, mouse, sound card, web browser.

EPE PIC RESOURCES V2



Version 2 includes the EPE PIC Tutorial V2 series of Supplements (EPE April, May, June 2003)

The CD-ROM contains the following Tutorial-related software and texts:

- EPE PIC Tutorial V2 complete series of articles plus demonstration software, John Becker, April, May, June '03
- PIC Toolkit Mk3 (TK3 hardware construction details), John Becker, Oct '01
- PIC Toolkit TK3 for Windows (software details), John Becker, Nov '01

Plus 18 useful texts to help you get the most out of your PIC programming.

Price **£14.75** inc. VAT

ELECTRONIC COMPONENTS PHOTOS

A high quality selection of over 200 jpg images of electronic components. This selection of high resolution photos can be used to enhance projects and presentations or to help with training and educational material. They are royalty free for use in commercial or personal printed projects, and can also be used royalty free in books, catalogues, magazine articles as well as worldwide web pages (subject to restrictions – see licence for full details).

Now contains Irfan View image software for Windows, with quick-start notes included.

Price **£19.95** inc. VAT

Please send me: CD-ROM ORDER FORM

- ☐ **Assembly for PICmicro V3**
- ☐ **'C' for 16 Series PICmicro V4**
- ☐ **Flowcode for PICmicro**
- ☐ **Flowcode for AVR**
- ☐ **Flowcode for ARM**
- ☐ **Flowcode for dsPIC & PIC24**

Version required:

- ☐ **Hobbyist/Student**
- ☐ **Professional**
- ☐ **Professional 10 user**
- ☐ **Professional + Flowkit**
- ☐ **Site licence**

Note: The software on each version is the same, only the licence for use varies.

- ☐ **PICmicro Development Board V3 (hardware)**

- ☐ **Circuit Wizard – Standard**
- ☐ **Circuit Wizard – Professional**
- ☐ **EPE PIC Resources V2**
- ☐ **Electronic Components Photos**

Full name: ....

Address: ....

.... Post code: .... Tel. No: ....

Signature: ....

☐ I enclose cheque/PO in £ sterling payable to WIMBORNE PUBLISHING LTD for £ ....

☐ Please charge my Visa/Mastercard/Maestro: £ ....

Valid From: .... Card expiry date: ....

Card No: .... Maestro Issue No. ....

Card Security Code .... (The last 3 digits on or just under the signature strip)

ORDERING
ALL PRICES INCLUDE UK POSTAGE

Student/Single User/Standard/Hobbyist Version price includes postage to most countries in the world
EU residents outside the UK add £5 for airmail postage per order

Professional, Multiple User and Site License Versions – overseas readers add £5 to the basic price of each order for airmail postage (**do not add VAT** unless you live in an EU (European Union) country, then add VAT at 20% or provide your official VAT registration number).

Send your order to:
Direct Book Service
Wimborne Publishing Ltd
113 Lynwood Drive, Merley, Wimborne, Dorset BH21 1UU
To order by phone ring
01202 880299. Fax: 01202 843233
Goods are normally sent within seven days
E-mail: orders@wimborne.co.uk
Online shop:
www.epemag.com

Net Work

Alan Winstanley

Mains Cable Network News

IN May's *Net Work,* I highlighted some interesting mains networking products that have arrived on the consumer market. The latest 500Mbps (maximum) consumer devices have the 1080p HD TV and 3D video markets in mind, and in theory they allow media and data – eg, videos or HD Sport downloaded on demand – to be transmitted to an Internet-enabled TV screen using the electricity supply instead of Ethernet cables. A Homeplug-type Ethernet main adaptor is simply hooked up to a spare router port and similar adaptors are used around the premises to network your laptops, games consoles, PCs or A/V equipment to your broadband service or to each other, through the ring mains.

A friend who tried some Homeplug adaptors wondered how to install the software (there wasn't any) because surely it could not be as simple as plugging it all together, but in theory it really is just a case of plug and play. As I discovered for myself, it does not work in all situations though. As

The Homeplug Power Alliance majors on utilising the IEEE 1901 standard for mains electrical networking

mentioned last month, all devices need to share the same electrical phase, and the further away the data has to be transmitted, the more likely it will be degraded, and electrical noise from motors or poor connections or powerstrips can impact on the quality of throughput, or cause the network connection to drop altogether. Gigabit network rates are promised in the near future.

Unfortunately for those of us caught up in the march of progress, there are two standards of mains power networking vying with each other – IEEE 1901 and the ITU-T standard G.hn. The Homeplug Power Alliance (**www.homeplug.org**) has majored on IEEE 1901 and its supporters include Sony, Devolo (see last month), LG, Maxim, Netgear, ST (SGS Thomson) and major US power companies. The competing Homegrid Forum (**www.homegridforum.org**) has nailed its colours to ITU G.hn instead, and the forum counts among its promoters Texas Instruments (which recently acquired chip maker National Semiconductor), the retail supergiant Best Buy, British Telecom, Telefonica (the name behind O2 mobile) and last but not least, Intel.

Moves are afoot to try to ensure that devices from both camps can co-exist on the same network, but doubts will rightly be raised in the minds of buyers, and there are no guarantees about cross-compatibility or retro compatibility either – never mind whether it can work on your own ring mains. When shopping around today, look for either the distinct Homeplug or Homegrid logos and it is probably safest to stick to one standard or the other for the time being.

You need HANs...

If anything, the choice of networking hardware is becoming more bewildering by the day, with broadband being exploited in the home in ways that were unthinkable 10 or 20 years ago. But it does not stop at audio-visual entertainment and the Home Area Network or HAN has seen nothing yet.

Interestingly, Homeplug Green PHY (physical layer) is a sub-set of this mains networking standard, intended to focus on Smart Grid applications with a view to reducing energy consumption. This includes 'smart' power meters, domestic heating and air-conditioning systems, smart thermostats or even electrical vehicle charging controls, all of which could be interrogated and optimised via Green PHY networking. Green PHY chipsets are designed to consume far less power themselves than current Homeplug devices. Homegrid's answer to Smart Grid networking is embraced by the forthcoming G.hnem standard.

The competing Homegrid Forum is dedicated to rolling out mains networking and Smart Grid applications that comply with ITU G.hn standard

With digital data now superimposed on the electrical supply, phone lines and co-axial cable, the amazing prospect of total home appliance interconnectivity heaves into view. Enter the world of 'domotics', the buzzword for home automation which will transform the way that electrical appliances are integrated into our lives. Given the prospect of finger-tip electronic control and home automation, and what domestic network control promises to deliver is nothing short of mind-boggling – no doubt controllable with an app for an iPad or mobile phone.

Next month, I'll look at some of the choices an aspiring 'Domestic Network Administrator' might face when considering streaming TV or media around the home. You can email me at: **alan@epemag.demon.co.uk**


Laser
Why tolerate when you can automate?
X-10 Home Automation
KAT5 AV transmission and IR control system
Barix Ethernet based MP3, communications and control systems
www.laser.com
Integrators, Installers, Trade and Retail customers welcome
C-Bus Shop
C-Bus and C-Bus Wireless
www.cbus-shop.com
Laser Business Systems Ltd
Tel: +44 (0) 20 8441 9788
Fax: +44 (0) 20 8449 0430
Email: info@laser.com
16 Garthland Drive, EN5 3BB


TO ADVERTISE IN
EVERYDAY PRACTICAL ELECTRONICS
PLEASE CONTACT
Stewart Kearn on
01202 880299
or email
stewart.kearn@wimborne.co.uk


CRICKLEWOOD ELECTRONICS
Established 1981
Frustrated with your supplier? Visit our component packed website for a vast range of parts - old and new, many unavailable elsewhere!
www.cricklewoodelectronics.com
1000's OF PRICES REDUCED!
Alternatively phone us on 020 8452 0161 with your requirements.
Visit our Shop, Call or Buy online at:
www.cricklewoodelectronics.com
020 8452 0161
Visit our shop at:
40-42 Cricklewood Broadway
London NW2 3ET


EPE BINDERS
KEEP YOUR MAGAZINES SAFE – RING US NOW!
This ring binder uses a special system to allow the issues to be easily removed and re-inserted without any damage. A nylon strip slips over each issue and this passes over the four rings in the binder, thus holding the magazine in place.
The binders are finished in hard-wearing royal blue PVC. They will keep your issues neat and tidy but allow you to remove them for use easily.
The price is £7.95 plus £3.50 post and packing. If you order more than one binder add £1 postage each binder after the initial postage charge (overseas readers the postage is £6.00 each to everywhere except Australia and New Guinea which costs £10.50 each).
Send your payment in £'s sterling cheque or PO (Overseas readers send £ sterling bank draft, or cheque drawn on a UK bank or pay by card), to:
VISA
Maestro
MasterCard
Everyday Practical Electronics, Wimborne Publishing Ltd, 113 Lynwood Drive, Merley, Wimborne, Dorset, BH21 1UU.
Tel: 01202 880299. Fax: 01202 843233.
E-mail: editorial@epemag.wimborne.co.uk.
Web site: http://www.epemag.com
We also accept card payments. Mastercard, Visa, or Maestro. Send your card number and card valid from and expiry date plus Maestro Issue No. and the security code on the back of the card with your order.


Technobots
Electronic & Mechanical Components
With over 5,100 products available to order online, Technobots provides one of the widest range of components for the electronics and engineering enthusiast
Opto Electronics
Battery Products Chargers & PSU's
Controller Boards Including Arduino
Passsives, Semiconductors Sensors connectors etc..
Gears, Pulleys & Cams
Breakout Boards from Sparkfun
Pneumatics
Bearings from 1mm bore
Shafts & Adaptors
Chain & sprockets
Switches & Relays
160+ dc model motors + speed controllers
Projects & kits
Robotics & Wheels
LCD displays
Cable, Fuses &etc..
Tools
Education Accounts Welcome
Get our 120 page A4 catalogue free with your next order by quoting 'discount coupon code' EPE05 at the checkout
www.technobotsonline.com
Shop callers welcome: Technobots Ltd, 60 Rumbridge Street, Totton, Hampshire SO40 9DS Tel: 023 8086 4891

NEW

Electronics Teach-In 3

FREE CD-ROM

The three sections of this book cover a very wide range of subjects that will interest everyone involved in electronics, from hobbyists and students to professionals. The first 80-odd pages of Teach-In 3 are dedicated to *Circuit Surgery*, the regular *EPE* clinic dealing with readers' queries on various circuit design and application problems – everything from voltage regulation to using SPICE circuit simulation software.

The second section – *Practically Speaking* – covers the practical aspects of electronics construction. Again, a whole range of subjects, from soldering to avoiding problems with static electricity and indentifying components, are covered.

Finally, our collection of *Ingenuity Unlimited* circuits provides over 40 different circuit designs submitted by the readers of *EPE*.

The free cover-mounted CD-ROM is the complete *Electronics Teach-In 1* book, which provides a broad-based introduction to electronics in PDF form, plus interactive quizzes to test your knowledge, TINA circuit simulation software (a limited version – plus a specially written TINA Tutorial), together with simulations of the circuits in the Teach-In 1 series, plus Flowcode (a limited version) a high level programming system for PIC microcontrollers based on flowcharts.

The Teach-In 1 series covers everything from Electric Current through to Microprocessors and Microcontrollers and each part includes demonstration circuits to build on breadboards or to simulate on your PC. There is also a MW/LW Radio project in the series.

The contents of the book and Free CD-ROM have been reprinted from past issues of *EPE*.

160 pages+CD-ROM **Order code ET3** **£8.50**

ROBOTICS

INTRODUCING ROBOTICS WITH LEGO MINDSTORMS
Robert Penfold

Shows the reader how to build a variety of increasingly sophisticated computer controlled robots using the brilliant Lego Mindstorms Robotic Invention System (RIS). Initially covers fundamental building techniques and mechanics needed to construct strong and efficient robots using the various "click-together" components supplied in the basic RIS kit. Then explains in simple terms how the "brain" of the robot may be programmed on screen using a PC and "zapped" to the robot over an infra-red link. Also, shows how a more sophisticated Windows programming language such as Visual BASIC may be used to control the robots.

Detailed building and programming instructions provided, including numerous step-by-step photographs.

288 pages - large format **Order code BP901** **£14.99**

MORE ADVANCED ROBOTICS WITH LEGO MINDSTORMS – Robert Penfold

Shows the reader how to extend the capabilities of the brilliant Lego Mindstorms Robotic Invention System (RIS) by using lego's own accessories and some simple home constructed units. You will be able to build robots that can provide you with 'waiter service' when you clap your hands, perform tricks, 'see' and avoid objects by using 'bats radar', or accurately follow a line marked on the floor. Learn to use additional types of sensors including rotation, light, temperature, sound and ultrasonic and also explore the possibilities provided by using an additional (third) motor. For the less experienced, RCX code programs accompany most of the featured robots. However, the more adventurous reader is also shown how to write programs using Microsoft's VisualBASIC running with the ActiveX control (Spirit.OCX) that is provided with the RIS kit.

Detailed building instructions are provided for the featured robots, including numerous step-by-step photographs. The designs include rover vehicles, a virtual pet, a robot arm, an 'intelligent' sweet dispenser and a colour conscious robot that will try to grab objects of a specific colour.

198 pages **Order code BP902** **£14.99**

ANDROIDS, ROBOTS AND ANIMATRONS
Second Edition – John Iovine

Build your own working robot or android using both off-the-shelf and workshop constructed materials and devices. Computer control gives these robots and androids two types of artificial intelligence (an expert system and a neural network). A lifelike android hand can be built and programmed to function doing repetitive tasks. A fully animated robot or android can also be built and programmed to perform a wide variety of functions.

The contents include an Overview of State-of-the-Art Robots; Robotic Locomotion; Motors and Power Controllers; All Types of Sensors; Tilt; Bump; Road and Wall Detection; Light; Speech and Sound Recognition; Robotic Intelligence (Expert Type) Using a Single-Board Computer Programmed in BASIC; Robotic Intelligence (Neutral Type) Using Simple Neural Networks (Insect Intelligence); Making a Lifelike Android Hand; A Computer-Controlled Robotic Insect Programmed in BASIC; Telepresence Robots With Actual Arcade and Virtual Reality Applications; A Computer-Controlled Robotic Arm; Animated Robots and Androids; Real-World Robotic Applications.

224 pages **Order code MGH1** **£16.99**

DIRECT BOOK SERVICE

The books listed have been selected by *Everyday Practical Electronics* editorial staff as being of special interest to everyone involved in electronics and computing. They are supplied by mail order direct to your door. Full ordering details are given on the last book page.

FOR A FURTHER SELECTION OF BOOKS SEE THE NEXT TWO ISSUES OF *EPE*

3 **All prices include UK postage**

RADIO

BASIC RADIO PRINCIPLES AND TECHNOLOGY
Ian Poole

Radio technology is becoming increasingly important in today's high technology society. There are the traditional uses of radio which include broadcasting and point to point radio as well as the new technologies of satellites and cellular phones. All of these developments mean there is a growing need for radio engineers at all levels.

Assuming a basic knowledge of electronics, this book provides an easy to understand grounding in the topic.

Chapters in the book: Radio Today, Yesterday, and Tomorrow; Radio Waves and Propagation; Capacitors, Inductors, and Filters; Modulation; Receivers; Transmitters; Antenna Systems; Broadcasting; Satellites; Personal Communications; Appendix – Basic Calculations.

263 pages **Order code NE30** **£28.99**

PROJECTS FOR RADIO AMATEURS AND S.W.L.S.
R. A. Penfold

This book describes a number of electronic circuits, most of which are quite simple, which can be used to enhance the performance of most short wave radio systems.

The circuits covered include: An aerial tuning unit; A simple active aerial; An add-on b.f.o. for portable sets; A wavetrap to combat signals on spurious responses; An audio notch filter; A parametric equaliser; C.W. and S.S.B. audio filters; Simple noise limiters; A speech processor; A volume expander.

Other useful circuits include a crystal oscillator, and RTTY/C.W. tone decoder, and a RTTY serial to parallel converter. A full range of interesting and useful circuits for short wave enthusiasts.

92 pages **Order code BP304** **£4.45**

AN INTRODUCTION TO AMATEUR RADIO
I. D. Poole

Amateur radio is a unique and fascinating hobby which has attracted thousands of people since it began at the turn of the last century. This book gives the newcomer a comprehensive and easy to understand guide through the subject so that the reader can gain the most from the hobby. It then remains an essential reference volume to be used time and again. Topics covered include the basic aspects of the hobby, such as operating procedures, jargon and setting up a station. Technical topics covered include propagation, receivers, transmitters and aerials etc.

150 pages **Order code BP257** **£5.49**

COMPUTERS AND COMPUTING

ELECTRONICS TEACH-IN 2 CD-ROM

CD-ROM

USING PIC MICROCONTROLLERS A PRACTICAL INTRODUCTION

This *Teach-In* series of articles was originally published in *EPE* in 2008 and, following demand from readers, has now been collected together in the *Electronics Teach-In 2* CD-ROM.

The series is aimed at those using PIC microcontrollers for the first time. Each part of the series includes breadboard layouts to aid understanding and a simple programmer project is provided.

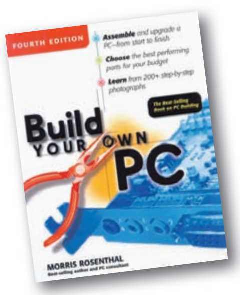
Also included are 29 *PIC N' Mix* articles, also republished from *EPE*. These provide a host of practical programming and interfacing information, mainly for those that have already got to grips with using PIC microcontrollers.

An extra four part beginners guide to using the C programing language for PIC microcontrollers is also included.

The CD-ROM also contains all of the software for the *Teach-In 2* series and *PIC N' Mix* articles, plus a range of items from Microchip – the manufacturers of the PIC microcontrollers. The material has been compiled by Wimborne Publishing Ltd. with the assistance of Microchip Technology Inc.

The Microchip items are: MPLAB Integrated Development Environment V8.20; Microchip Advance Parts Selector V2.32; Treelink; Motor Control Solutions; 16-bit Embedded Solutions; 16-bit Tool Solutions; Human Interface Solutions; 8-bit PIC Microcontrollers; PIC24 Micrcontrollers; PIC32 Microcontroller Family with USB On-The-Go; dsPIC Digital Signal Controllers.

CD-ROM **Order code ETI2 CD-ROM** **£9.50**



BUILD YOUR OWN PC – Fourth Edition
Morris Rosenthal

More and more people are building their own PCs. They get more value for their money, they create exactly the machine they want, and the work is highly satisfying and actually fun. That is, if they have a unique beginner's guide like this one, which visually demonstrates how to construct a computer from start to finish.

Through 150 crisp photographs and clear but minimal text, readers will confidently absorb the concepts of computer building. The extra-big format makes it easy to see what's going on in the pictures. The author goes 'under the hood' and shows step-by-step how to create a Pentium 4 computer or an Athlon 64 or Athlon 64FX, covering: What first-time builders need to know; How to select and purchase parts; How to assemble the PC; How to install Windows XP. The few existing books on this subject, although outdated, are in steady demand. This one delivers the expertise and new technology that fledgling computer builders are looking for.

224 pages - large format **Order code MGH2** **£16.99**

PROGRAMMING 16-BIT PIC MICROCONTROLLERS IN C – LEARNING TO FLY THE PIC24 Lucio Di Jasio (Application Segments Manager, Microchip, USA)

A Microchip insider tells all. Focuses on examples and exercises that show how to solve common, real-world design problems quickly. Includes handy checklists to help readers perform the most common programming and debugging tasks. FREE CD-ROM includes source code in C, the Microchip C30 compliler, and MPLAB SIM software, so that readers gain practical, hands-on programming experience.

Until recently, PICs didn't have the speed and memory necessary for use in designs such as video- and audio-enabled devices. All that changed with the introduction of the 16-bit PIC family, the PIC24. This new guide teaches readers everything they need to know about the architecture of these chips, how to program them, how to test them and how to debug them. Lucio's common-sense, practical, hands-on approach starts out with basic functions and guides the reader step-by-step through even the most sophisticated programming scenarios.

Experienced PIC users and newcomers alike will benefit from the text's many thorough examples, which demonstrate how to nimbly side-step common obstacles and take full advantage of all the 16-bit features.

496 pages +CD-ROM **Order code NE45** **£38.00**

NEW FULL COLOUR COMPUTING BOOKS

WINDOWS 7 – TWEAKS, TIPS AND TRICKS
Andrew Edney

This book will guide you through many of the exciting new features of Windows 7. Microsoft's latest and greatest operating system. It will provide you with useful hints, tips and warnings about possible difficulties and pitfalls. This book should enable you to get much more out of Windows 7 and, hopefully, discover a few things that you may not have realised were there.

Among the topics covered are: A brief overview of the various versions of Windows 7. How to install and use Upgrade Advisor, which checks to see if your computer meets the minimum requirements to run Windows 7 and that your software and drivers are supported by Windows 7. How to use Windows Easy Transfer to migrate your data and settings from your Vista or XP machine to your new Windows 7 computer. Exploring Windows 7 so that you will become familiar with many of its new features and then see how they contrast with those of earlier versions of Windows. How to connect to a network and create and use Home Groups to easily share your pictures, videos, documents, etc.,with the minimum of hassle. Why Windows Live Essentials is so useful and how to download and install it. A brief introduction to Windows Media Center. The use of Action Center, which reports security and maintenance incidents. Windows Memory Diagnostic to detect the fairly common problem of faulty memory and Troubleshooting tools.

120 pages — **Order code BP708** — **£8.49**

HOW TO BUILD A COMPUTER MADE EASY
R.A. Penfold

Building your own computer is a much easier than most people realise and can probably be undertaken by anyone who is reasonably practical. However, some knowledge and experience of using a PC would be beneficial. This book will guide you through the entire process. It is written in a simple and straightforward way with the explanations clearly illustrated with numerous colour photographs.

The book is divided into three sections: *Overview and preparation* – Covers understanding the fundamentals and choosing the most suitable component parts for your computer, together with a review of the basic assembly. *Assembly* – Explains in detail how to fit the component parts into their correct positions in the computer's casing, then how to connect these parts together by plugging the cables into the appropriate sockets. No soldering should be required and the only tools that you are likely to need are screwdrivers, small spanners and a pair of pliers.

BIOS and operating system – This final section details the setting up of the BIOS and the installation of the Windows operating system, which should then enable all the parts of your computer to work together correctly. You will then be ready to install your files and any application software you may require.

The great advantage of building your own computer is that you can 'tailor' it exactly to your own requirements. Also, you will learn a tremendous amount about the structure and internal workings of a PC, which will prove to be invaluable should problems ever arise.

120 pages — **Order code BP707** — **£8.49**

AN INTRDUCTION TO eBAY FOR THE OLDER GENERATION
Cherry Nixon

eBay is an online auction site that enables you to buy and sell practically anything from the comfort of your own home. eBay offers easy access to the global market at an amazingly low cost and will enable you to turn your clutter into cash.

This book is an introduction to eBay.co.uk and has been specifically written for the over 50s who have little knowledge of computing. The book will, of course, also apply equally to all other age groups. The book contains ideas for getting organised for long term safe and successful trading. You will learn how to search out and buy every conceivable type of thing.The book also shows you how to create auctions and add perfect pictures. There is advice on how to avoid the pitfalls that can befall the inexperienced.

Cherry Nixon is probably the most experienced teacher of eBay trading in the UK and from her vast experience has developed a particular understanding of the issues and difficulties normally encountered by individuals.

So, if you are new to computers and the internet and think of a mouse as a rodent, then this is the book for you!

120 pages — **Order code BP709** — **£8.49**

GETTING STARTED IN COMPUTING FOR THE OLDER GENERATION
Jim Gatenby

You can learn to use a computer at any age and this book will help you acheive this. It has been especially written for the over 50s, using plain English and avoiding technical jargon wherever possible. It is lavishly illustrated in full colour.

Among the many practical and useful subjects that are covered in this book are: Choosing the best computing system for your needs. Understanding the main hardware components of your computer. Getting your computer up and runnning in your home. Setting up peripheral devices like printers and routers. Connecting to the internet using wireless broadband in a home with one or more computers. Getting familiar with Windows Vista and XP the software used for operating and maintaining your computer. Learning about Windows built-in programs such as Windows Media Player, Paint and Photo Gallery.

Plus, using the Ease of Access Center to help if you have impaired eyesight, hearing or dexterity problems. Installing and using essential software such as Microsoft Office suite. Searching for the latest information on virtually any subject. Keeping in touch with friends and family using e-mail. Keeping your computer running efficiently and your valuable data files protected against malicious attack.

This book will help you to gain the basic knowledge needed to get the most out of your computer and, if you so wish, give you the confidence to even join a local computer class.

120 pages — **Order code BP704** — **£8.49**

THEORY AND REFERENCE

ELECTRONIC CIRCUITS – FUNDAMENTALS & APPLICATIONS
Third Edition
Mike Tooley

A comprehensive reference text and practical electronics handbook in one volume – at an affordable price!

New chapter on PIC microcontrollers – the most popular chip family for use in project work by hobbyists and in colleges and universities.

New companion website: spreadsheet design tools to simplify circuit calculations; circuit models and templates to enable virtual simulation; a bank of on-line questions for lecturers to set as assignments, and on-line self-test multiple choice questions for each chapter with automatic marking, to enable students to continually monitor their progress and understanding.

The book's content is matched to the latest pre-degree level courses, making this an invaluable reference for all study levels, and its broad coverage is combined with practical case studies, based in real-world engineering contexts throughout the text.

The unique combination of a comprehensive reference text, incorporating a primary focus on practical applications, ensures this text will prove a vital guide for students and also for industry-based engineers, who are either new to the field of electronics, or who wish to refresh their knowledge.

400 pages — **Order code NE43** — **£25.99**

BEBOP TO THE BOOLEAN BOOGIE
Third Edition
Clive (Max) Maxfield

This book gives the 'big picture' of digital electronics. This indepth, highly readable, guide shows you how electronic devices work and how they're made. You'll discover how transistors operate, how printed circuit boards are fabricated, and what the innards of memory ICs look like. You'll also gain a working knowledge of Boolean Algebra and Karnaugh Maps, and understand what Reed-Muller logic is and how it's used. And there's much, MUCH more. The author's tongue-in-cheek humour makes it a delight to read, but this is a REAL technical book, extremely detailed and accurate.

Contents: Fundamental concepts; Analog versus digital; Conductors and insulators; Voltage, current, resistance, capacitance and inductance; Semiconductors; Primitive logic functions; Binary arithmetic; Boolean algebra; Karnaugh maps; State diagrams, tables and machines; Analog-to-digital and digital-to-analog; Integrated circuits (ICs); Memory ICs; Programmable ICs; Application-specific integrated circuits (ASICs); Circuit boards (PWBs and DWBs); Hybrids; Multichip modules (MCMs); Alternative and future technologies.

500 pages — **Order code BEB1** — **£32.99**

BEBOP BYTES BACK (and the Beboputer Computer Simulator) CD-ROM
Clive (Max) Maxfield and Alvin Brown

CD-ROM

This follow-on to Bebop to the Boolean Boogie is a multimedia extravaganza of information about how computers work. It picks up where "Bebop I" left off, guiding you through the fascinating world of computer design . . . and you'll have a few chuckles, if not belly laughs, along the way. In addition to over 200 megabytes of mega-cool multimedia, the CD-ROM contains a virtual microcomputer, simulating the motherboard and standard computer peripherals in an extremely realistic manner. In addition to a wealth of technical information, myriad nuggets of trivia, and hundreds of carefully drawn illustrations, the CD-ROM contains a set of lab experiments for the virtual microcomputer that let you recreate the experiences of early computer pioneers. if you're the slightest bit interested in the inner workings of computers, then don't dare to miss this!

Over 800 pages in Adobe Acrobat format

CD-ROM — **Order code BEB2 CD-ROM** — **£21.95**

FUNDAMENTAL ELECTRICAL AND ELECTRONIC PRINCIPLES
Third Edition
C. R. Robertson

Covers the essential principles that form the foundations for electrical and electronic engineering courses. The coverage of this new edition has been carefully brought in line with the core unit 'Electrical and Electronic Principles' of the 2007 BTEC National Engineering specification. This qualification from Edexcel attracts more than 10,000 students per year.

The book explains all theory in detail and backs it up with numerous worked examples. Students can test their understanding with end of chapter assignment questions for which answers are provided. In this new edition, the layout has been improved and colour has been added. A free companion website with additional worked examples and chapters is also available.

368 pages — **Order code NE47** — **£21.99**

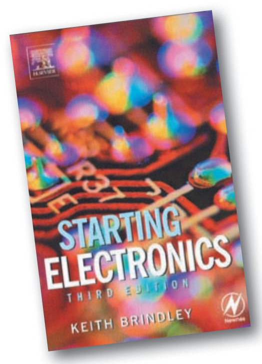
STARTING ELECTRONICS
Third Edition
Keith brindley

A punchy practical introduction to self-build electronics. The ideal starting point for home experimenters, technicians and students who want to develop the real hands-on skills of electronics construction.

A highly practical introduction for hobbyists, students, and technicians. Keith Brindley introduces readers to the functions of the main component types, their uses, and the basic principles of building and designing electronic circuits.

Breadboard layouts make this very much a ready-to-run book for the experimenter, and the use of multimeter, but not oscilloscopes, and readily available, inexpensive components makes the practical work achievable in a home or school setting as well as a fully equiped lab.

Temporarily out of print



MUSIC, AUDIO AND VIDEO

MAKING MUSIC WITH YOUR COMPUTER
Stephen Bennett
Nearly everyone with musical aspirations also has a computer. This same computer can double as a high quality recording studio capable of producing professional recordings. This book tells you what software and hardware you will need to get the best results.
You'll learn about recording techniques, software and effects, mixing, mastering and CD production.
Suitable for PC and Mac users, the book is full of tips, "how to do" topics and illustrations. It's the perfect answer to the question "How do I use my computer to produce my own CD?"

92 pages **Order code PC120** **£10.95**

QUICK GUIDE TO MP3 AND DIGITAL MUSIC
Ian Waugh
MP3 files, the latest digital music format, have taken the music industry by storm. What are they? Where do you get them? How do you use them? Why have they thrown record companies into a panic? Will they make music easier to buy? And cheaper? Is this the future of music?
All these questions and more are answered in this concise and practical book which explains everything you need to know about MP3s in a simple and easy-to-understand manner. It explains:
How to play MP3s on your computer; How to use MP3s with handheld MP3 players; Where to find MP3s on the Web; How MP3s work; How to tune into Internet radio stations; How to create your own MP3s; How to record your own CDs from MP3 files; Other digital audio music formats.
Whether you want to stay bang up to date with the latest music or create your own MP3s and join the on-line digital music revolution, this book will show you how.

60 pages **Order code PC119** **£7.45**

VIDEO PROJECTS FOR THE ELECTRONICS CONSTRUCTOR
R. A. Penfold
Written by highly respected author R. A. Penfold, this book contains a collection of electronic projects specially designed for video enthusiasts. All the projects can be simply constructed, and most are suitable for the newcomer to project construction, as they are assembled on stripboard.
There are faders, wipers and effects units which will add sparkle and originality to your video recordings, an audio mixer and noise reducer to enhance your soundtracks and a basic computer control interface. Also, there's a useful selection on basic video production techniques to get you started.
Complete with explanations of how the circuit works, shopping lists of components, advice on construction, and guidance on setting up and using the projects, this invaluable book will save you a small fortune.
Circuits include: video enhancer, improved video enhancer, video fader, horizontal wiper, improved video wiper, negative video unit, fade to grey unit, black and white keyer, vertical wiper, audio mixer, stereo headphone amplifier, dynamic noise reducer, automatic fader, pushbutton fader, computer control interface, 12 volt mains power supply.

124 pages **Order code PC115** ~~£10.95~~ **£5.45**

RADIO BYGONES

We also carry a selection of books aimed at readers of *EPE*'s sister magazine on vintage radio *Radio Bygones*. These books include, the four volumes of our own *Wireless For the Warrior* by Louis Meulstee. These are a technical history of radio communication equipment in the British Army and clandestine equipment from pre-war through to the 1960s.
For details see the UK shop on our web site at www.epemag.com or contact us for a list of *Radio Bygones* books.

PROJECT BUILDING AND TESTING

ELECTRONIC PROJECT BUILDING FOR BEGINNERS
R. A. Penfold
This book is for complete beginners to electronic project building. It provides a complete introduction to the practical side of this fascinating hobby, including the following topics:
Component identification, and buying the right parts; resistor colour codes, capacitor value markings, etc; advice on buying the right tools for the job; soldering; making easy work of the hard wiring; construction methods, including stripboard, custom printed circuit boards, plain matrix boards, surface mount boards and wire-wrapping; finishing off, and adding panel labels; getting "problem" projects to work, including simple methods of fault-finding.
In fact everything you need to know in order to get started in this absorbing and creative hobby.

135 pages **Order code BP392** **£5.99**

BUILDING VALVE AMPLIFIERS
Morgan Jones
The practical guide to building, modifying, fault-finding and repairing valve amplifiers. A hands-on approach to valve electronics – classic and modern – with a minimum of theory. Planning, fault-finding, and testing are each illustrated by step-by-step examples.
A unique hands-on guide for anyone working with valve (tube in USA) audio equipment – as an electronics experimenter, audiophile or audio engineer.
Particular attention has been paid to answering questions commonly asked by newcomers to the world of the vacuum tube, whether audio enthusiasts tackling their first build, or more experienced amplifier designers seeking to learn the ropes of working with valves. The practical side of this book is reinforced by numerous clear illustrations throughout.

368 pages **Order code NE40** **£29.00**

PRACTICAL FIBRE-OPTIC PROJECTS
R. A. Penfold
While fibre-optic cables may have potential advantages over ordinary electric cables, for the electronics enthusiast it is probably their novelty value that makes them worthy of exploration. Fibre-optic cables provide an innovative interesting alternative to electric cables, but in most cases they also represent a practical approach to the problem. This book provides a number of tried and tested circuits for projects that utilize fibre-optic cables.
The projects include:- Simple audio links, F.M. audio link, P.W.M. audio links, Simple d.c. links, P.W.M. d.c. link, P.W.M. motor speed control, RS232C data links, MIDI link, Loop alarms, R.P.M. meter.
All the components used in these designs are readily available, none of them require the constructor to take out a second mortgage.

132 pages **Order code BP374** **£5.45**

GETTING THE MOST FROM YOUR MULTIMETER
R. A. Penfold
This book is primarily aimed at beginners and those of limited experience of electronics. Chapter 1 covers the basics of analogue and digital multimeters, discussing the relative merits and the limitations of the two types. In Chapter 2 various methods of component checking are described, including tests for transistors, thyristors, resistors, capacitors and diodes. Circuit testing is covered in Chapter 3, with subjects such as voltage, current and continuity checks being discussed.
In the main little or no previous knowledge or experience is assumed. Using these simple component and circuit testing techniques the reader should be able to confidently tackle servicing of most electronic projects.

102 pages **Order code BP239** **£5.49**

BOOK ORDERING DETAILS

All prices include UK postage. For postage to Europe (air) and the rest of the world (surface) please add £3 per book. Surface mail can take up to 10 weeks to some countries. For the rest of the world airmail add £4 per book. CD-ROM prices include VAT and/or postage to anywhere in the world. Send a PO, cheque, international money order (£ sterling only) made payable to **Direct Book Service** or card details, Visa, Mastercard or Maestro to: **DIRECT BOOK SERVICE, WIMBORNE PUBLISHING LIMITED, 113 LYNWOOD DRIVE, MERLEY, WIMBORNE, DORSET BH21 1UU**.

Books are normally sent within seven days of receipt of order, but please allow 28 days for delivery – more for overseas orders. *Please check price and availability (see latest issue of* Everyday Practical Electronics*) before ordering from old lists.*

For a further selection of books see the next two issues of *EPE*.
Tel 01202 880299 Fax 01202 843233. E-mail: dbs@wimborne.co.uk

Order from our online shop at: www.epemag.com – go to the UK store

BOOK ORDER FORM

Full name: ....

Address: ....

....

....

.... Post code: .... Telephone No: ....

Signature: ....

☐ I enclose cheque/PO payable to DIRECT BOOK SERVICE for £ ....

☐ Please charge my card £ .... Card expiry date.......................................

Card Number .... Maestro Issue No............................

Valid From Date .... Card Security Code .... (The last three digits on or just below the signature strip)

Please send book order codes: ....

....

Please continue on separate sheet of paper if necessary

PCB SERVICE

Printed circuit boards for most recent *EPE* constructional projects are available from the *PCB Service*, see list. These are fabricated in glass fibre, and are fully drilled and roller tinned. Double-sided boards are **NOT plated through hole** and will require 'vias' and some components soldering to both sides. All prices include VAT and postage and packing. Add £1 per board for airmail outside of Europe. Remittances should be sent to **The PCB Service, Everyday Practical Electronics, Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset BH21 1UU. Tel: 01202 880299; Fax 01202 843233; Email: orders@epemag.wimborne.co.uk. On-line Shop: www.epemag.com**. Cheques should be crossed and made payable to *Everyday Practical Electronics* **(Payment in £ sterling only)**.

NOTE: While 95% of our boards are held in stock and are dispatched within seven days of receipt of order, please allow a maximum of 28 days for delivery – overseas readers allow extra if ordered by surface mail. Back numbers or photocopies of articles are available if required – see the Back Issues page for details. WE DO NOT SUPPLY KITS OR COMPONENTS FOR OUR PROJECTS.

Please check price and availability in the latest issue. A large number of older boards are listed on, and can be ordered from, our website.

Boards can only be supplied on a payment with order basis.

PROJECT TITLE	ORDER CODE	COST
APRIL '10		
USB Power Injector	597	£6.46
Alternative 12V 10A Power Supply	751	£7.88
LM3909 Replacement Module	752	£6.62
MAY '10		
★ Water Tank Level Meter	753	£7.33
★ dsPIC/PIC Programmer – Main Board	754 } set	£9.42
– Adaptor	755	
JUNE '10		
★ PIC-Based Musical Tuning Aid	756	£9.06
★ Water Tank Level Meter – Base	757 } set	£7.67
– Switch	758	
★ DSP Musicolour – Main	759 } set	£16.49
– Display	760	
JULY '10		
★ ColdAlert Hypothermia Alarm	761	£7.68
★ Swimming Pool Alarm	762	£8.37
AUGUST '10		
★ PIC-Based Flexitimer (double-sided)	763	£12.91
DSP Musicolour – Remote Control Receiver	764	£5.93
★ UV Lightbox – Exposure Controller	765 } set	£9.77
– Display/Timer	766	
Ultra LD 200W Power Amplifier (double-sided)	767	£15.52
SEPTEMBER '10		
Ultra-LD 200W Power Amplifier – Power Supply	768	£8.37
Low-Voltage Adjustable Regulator	769	£6.81
Balanced/Unbalanced Converter	770	£7.68
Planet Jupiter Receiver (double-sided)	771	£15.00
OCTOBER '10		
Bridge Adaptor For Stereo Power Amps	770	£7.68
CDI Module For Small Motors	772	£6.63
★ LED Strobe and Tachometer – 1		
– Main Board	775 } pair	£8.37
– Switch Board	776	
NOVEMBER '10		
★Railpower – Main Board	773 } pair	£14.83
– Display Board	774	
★LED Strobe and Tachometer – 2		
– Photo-Interrupter	777 } pair	£7.15
– IR Reflect Amp	778	
★USB Clock with LCD Readout – 1	779	£7.85
Balanced MIC Preamp for PCs and MP3 Players	780	£8.72
DECEMBER '10		
12V Speed Controller or 12V Lamp Dimmer	781	£6.99
★Digital RF Level & Power Meter		
– Main Board	783 } set	£10.81
– Head-end Board	784	
– RF Attenuator Board	785	

PROJECT TITLE	ORDER CODE	COST
JANUARY '11		
★Multi-Purpose Car Scrolling Display		
– Main Board	786 } pair	£12.21
– Display Board	787	
USB-Sensing Mains Power Switch	788	£9.77
★433MHz UHF Remote Switch		
– Transmitter	789 } pair	£10.12
– Receiver	790	
FEBRUARY '11		
Time Delay Photoflash Trigger	791	£9.72
Tempmaster Mk.2	792	£8.59
MARCH '11		
★GPS Synchronised Clock	793	£8.02
★Digital Audio Millivoltmeter	794	£11.34
Theremin	795	£10.53
USB Printer Share Switch	796	£6.80
APRIL '11		
Multi-Message Voice Recorder	797	£7.53
PIR-Triggered Mains Switch	798	£8.00
★Intelligent Remote-Controlled Dimmer	799	£6.97
MAY '11		
★6-Digit GPS Clock	800	£10.69
Simple Voltage Switch For Car Sensors	801	£6.80
The μCurrent (double-sided, surface mount)	802	£11.50
★Digital Audio Oscillator (double-sided)	803	£11.83
JUNE '11		
230V AC 10A Full-Wave Motor Speed Controller	804	£8.91
Precision 10V DC Voltage Reference	805	£6.48
6-Digit GPS Clock Driver (Pt.2)	806	£6.80
Musicolour IRDA Accessory	807	£6.15

EPE SOFTWARE

★ All software programs for *EPE* Projects marked with a star, and others previously published can be downloaded free from the Library on our website, accessible via our home page at: **www.epemag.com**

PCB MASTERS

PCB masters for boards published from the March '06 issue onwards can also be downloaded from our website (**www.epemag.com**); **go to the 'Library' section.**

EPE PRINTED CIRCUIT BOARD SERVICE

Order Code **Project** **Quantity** **Price**

. . . .

Name . . . .

Address . . . .

. . . .

Tel. No. . . . .

I enclose payment of £ . . . . (cheque/PO in **£ sterling only**) to:

Everyday Practical Electronics

MasterCard VISA Maestro

Card No. . . . .

Valid From . . . . Expiry Date . . . .

Card Security No. . . . . Maestro Issue No. . . . . . .

Signature . . . .

Note: You can also order PCBs by phone, Fax or Email or via the Shop on our website on a secure server:

http://www.epemag.com

CLASSIFIED
A D V E R T I S E M E N T S

Everyday Practical Electronics reaches more UK readers than any other UK monthly hobby electronics magazine, our sales figures prove it. We have been the leading monthly magazine in this market for the last twenty-five years.

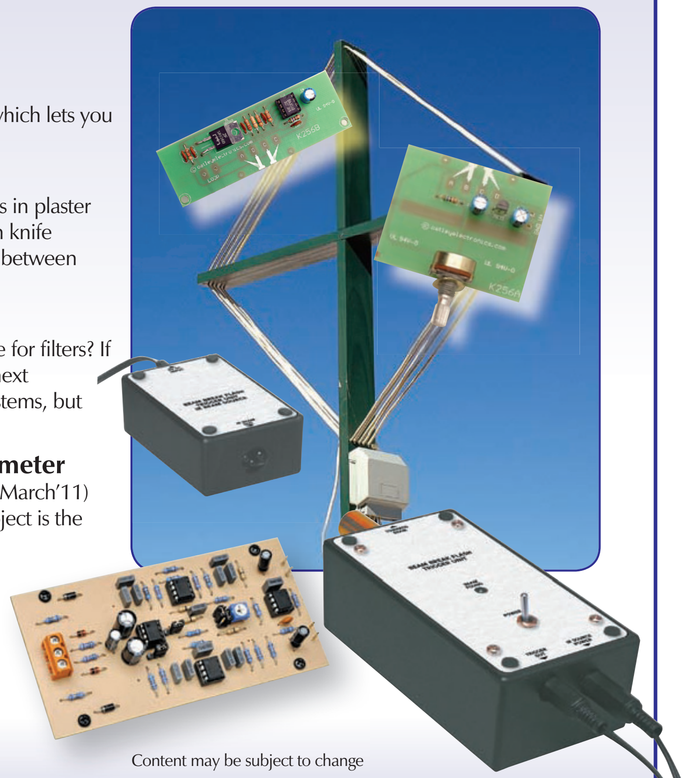
If you want your advertisements to be seen by the largest readership at the most economical price our classified page offers excellent value. The rate for semi-display space is £10 (+VAT) per centimetre high, with a minimum height of 2·5cm. All semi-display adverts have a width of 5.5cm. The prepaid rate for classified adverts is 40p (+VAT) per word (minimum 12 words).
All cheques, postal orders, etc., to be made payable to Everyday Practical Electronics. **VAT must be added**. Advertisements, together with remittance, should be sent to Everyday Practical Electronics Advertisements, 113 Lynwood Drive, Merley, Wimborne, Dorset, BH21 1UU. Phone: 01202 880299. Fax: 01202 843233. Email: epeads@wimborne.co.uk. For rates and information on display and classified advertising please contact our Advertisement Manager, Stewart Kearn as above.

ADVERTISERS INDEX

ADVERTISEMENT OFFICES:
113 LYNWOOD DRIVE, MERLEY, WIMBORNE, DORSET BH21 1UU
PHONE: 01202 880299 **FAX:** 01202 843233
EMAIL: epeads@wimborne.co.uk **WEB:** www.epemag.com

For editorial address and phone numbers see page 7

Next Month



Loop Antenna and Amplifier
A great little antenna project, small enough for domestic use, which lets you listen to faint AM radio stations and separate close stations.

Metal Locator
Perfect for finding steel frames and studs, steel bracing and nails in plaster walls, this Metal Locator can also show the length of the tang in knife handles, screwdrivers and other tools. It can even discriminate between ferrous and non-ferrous metals!

Multi-Function Active Filter Module
Did this issue's *Circuit Surgery* and *Teach-In* whet your appetite for filters? If so, you won't want to miss this versatile active filter project in next month's *EPE*. It's ideal as an active crossover in loudspeaker systems, but has lots of other uses as well.

Input attenuator for the Digital Audio Millivoltmeter
If you'd like to be able to use our *Digital Audio Millivoltmeter* (March'11) to measure AC voltages up to 140V RMS, then this add-on project is the answer. It's a simple switched input divider that lets you add 40dB, 20dB or 0dB of attenuation.

A Beam-Break Flash Trigger
Here's an easy-to-build accessory for the *Time Delay Photoflash Trigger* described in the February 2011 issue. It triggers the delay unit and your photoflash in response to an object interrupting an invisible beam of infrared (IR) light.

JULY '11 ISSUE – ON SALE 9 JUNE

Content may be subject to change

Published on approximately the second Thursday of each month by Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset BH21 1UU. Printed in England by Acorn Web Offset Ltd., Normanton, WF6 1TW. Distributed by Seymour, 86 Newman St., London W1T 3EX. Subscriptions INLAND: £19.95 (6 months); £37.90 (12 months); £70.50 (2 years). OVERSEAS: standard air service, £23.00 (6 months); £44.00 (12 months); £83.00 (2 years). Express airmail, £32.00 (6 months); £62.00 (12 months); £119.00 (2 years). Payments payable to "Everyday Practical Electronics'', Subs Dept, Wimborne Publishing Ltd. Email: subs@epemag.wimborne.co.uk. EVERYDAY PRACTICAL ELECTRONICS is sold subject to the following conditions, namely that it shall not, without the written consent of the Publishers first having been given, be lent, resold, hired out or otherwise disposed of by way of Trade at more than the recommended selling price shown on the cover, and that it shall not be lent, resold, hired out or otherwise disposed of in a mutilated condition or in any unauthorised cover by way of Trade or affixed to or as part of any publication or advertising, literary or pictorial matter whatsoever.